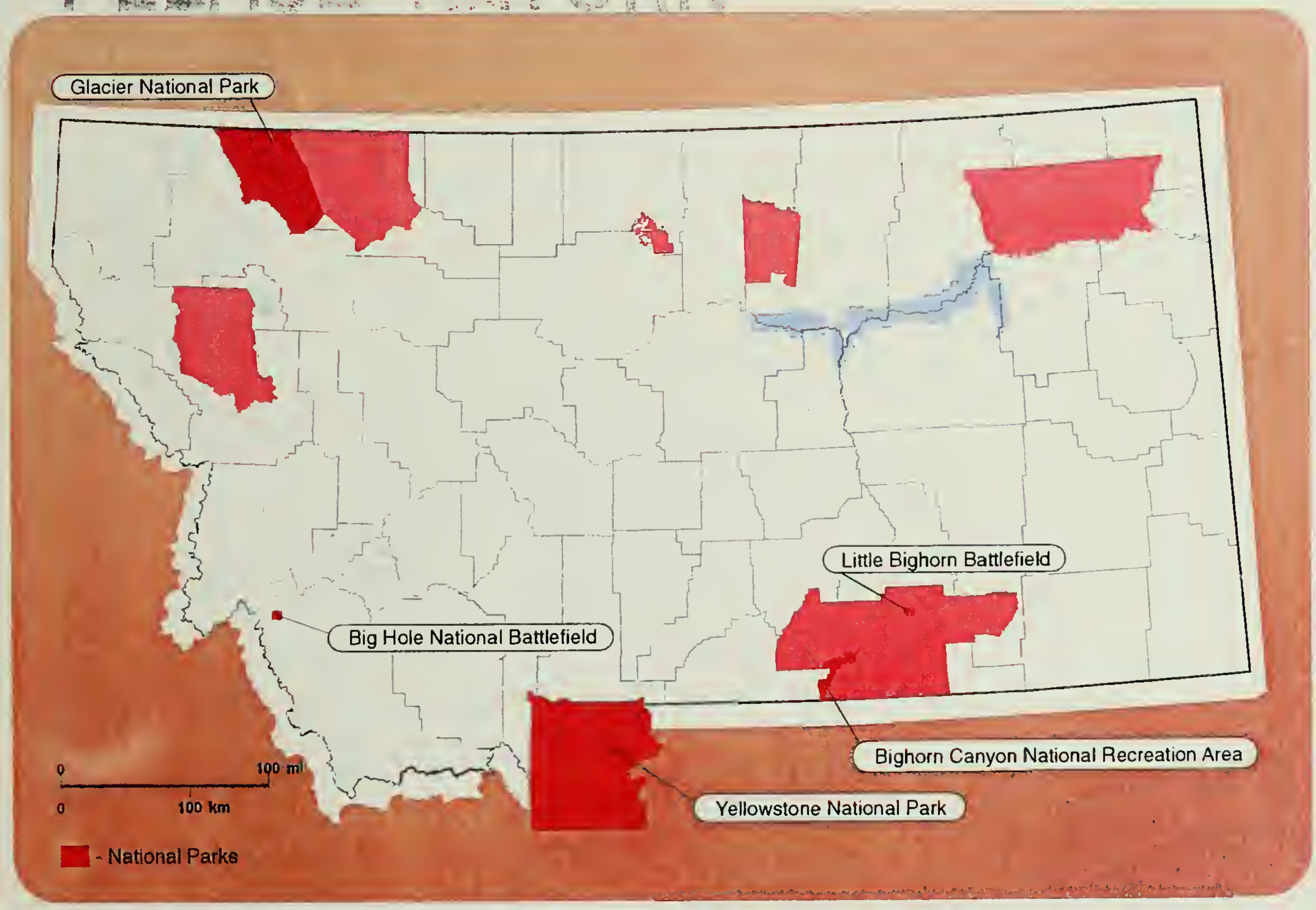
COMPACT SETTLEMENT BETWEEN

THE MONTANA RESERVED WATER RIGHTS COMPACT COMMISSION

AND THE

DEPARTMENT OF THE INTERIOR, NATIONAL PARK SERVICE

1993 and 1995



RESERVED WATER RIGHTS COMPACT COMMISSION STAFF
April 1997

MONTANA RESERVED WATER RIGHTS COMPACT COMMISSION

STAFF REPORT

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INTRODUCTION

Background of the Montana Reserved Water Rights Compact Commission

The Montana Reserved Water Rights Compact Commission was established by the Montana Legislature in 1979[1] to help integrate reserved water rights into the state adjudication process. The Commission is composed of nine members. Four members are appointed by the Governor, two members are appointed by the President of the Senate, two members are appointed by the Speaker of the House of Representatives, and one member is appointed by the Attorney General. Members serve 4 year terms.

The Commission is authorized to negotiate settlements with federal agencies and Indian tribes claiming federal reserved water rights within Montana.[2] A federal reserved water right is a right to use water that is implied from an act of Congress, a treaty, or an executive order establishing a tribal or federal reservation. It is a right that is recognized by federal law and need not be pursued through the standard state process for appropriation of water. The amount of water to which a reservation is entitled depends on the purpose for which the land was reserved. The water right does not require beneficial use and may not be lost through abandonment

In Montana, reserved water rights have been claimed for seven Indian reservations, including the Blackfeet, Rocky Boy's, Fort Belknap, Fort Peck, Flathead, Crow, Northern Cheyenne, and for allotments for the Turtle Mountain Chippewa Tribe. Federal agencies claiming reserved water rights include the National Park Service, the U.S. Forest Service, the Bureau of Land Management, and the U.S. Fish and Wildlife Service.

Legal and historical research and technical analyses are prepared for the Commission by a staff of eleven professional and technical members including a program manager, two attorneys, an agricultural engineer, a historical researcher, two hydrologists, a soils scientist, a geographic information specialist, and administrative staff.

Since its inception in 1979, the Commission has negotiated compacts with the Assiniboine and Sioux Tribes of the Fort Peck Reservation, the Northern Cheyenne Tribe, the National Park Service, the Bureau of Land Management, the U.S. Fish and Wildlife Service, and the Chippewa Cree Tribe of the Rocky Boy's Reservation. As required by Montana law, all five compacts have been approved by the Montana legislature. To date, only the Northern Cheyenne Compact has been entered in a decree by the Water Court.

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[1] 2-15-213[1] Montana Code Annotated.

[2] 2-15-701 Montana Code Annotated.

Background of Negotiations with the National Park Service

The federal government may reserve waters, making them unavailable for appropriation under state law.[3] In *Winters*, the United States Supreme Court held that the federal government does so by implication when it reserves land for an Indian Reservation if water is necessary to fulfill the purposes of the Reservation. In 1963, the Court made it clear that the implied reservation of water rights is equally applicable to non-Indian federal reservations when it endorsed a Special Master's findings of reserved water rights for a national recreation area and two national wildlife refuges.[4]

Allocation of water for use on private land and on public land that has not been reserved for a specific purpose is generally governed by state law.[5] Like most western states, Montana follows the doctrine of prior appropriation.[6] The Colorado Supreme Court summarized the basic incompatibilities between reserved and appropriative water rights by noting the following attributes of a reserved water right:

> (1) the right may be created without diversion or beneficial use; (2) the priority of the right dates from the time of the land withdrawal and not from the date of appropriation; (3) the right is not lost by nonuse; and (4) the measure of the right is quantified only by the amount of water reasonably necessary to satisfy the purposes of the reservation.[7]

For states in arid regions, the greatest source of conflict between appropriative and reserved water rights is created by new exercise of a reserved water right with a priority date that relates back to the date of the reservation.[8] Fueling this conflict is the fact that the United States did not begin to actively assert reserved water rights until the 1960s,[9] thus substantial development of junior water rights has occurred in some basins without consideration of water availability in light of the magnitude of reserved water rights.

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[3] *Winters v. United States*, 207 U.S. 564, 576 [1908].

[4] *Arizona v. California*, 373 U.S. 546, 601 [1963].

[5] *California Oregon Power Co. v. Beaver Portland Cement Co.*, 295 U.S. 142, 155 [1935].

[6] 85-2-401, MCA; *Mettler v. Ames Realty Co.*, 61 Mont. 152, 169-171 [1921].

[7] United States v. Jesse, 744 P.2d 491, 494 [Colo. 1987].

[8] See *Winters*, 207 U.S. at 577.

[9] See e.g., *Arizona v. California*, 373 U.S. 546 [1963].

Conflicts created by the legal differences between reserved and appropriative rights are further aggravated by the complexities of land ownership. Montana is a headwater state for the Columbia, Missouri, and Hudson rivers. The State contains 28% federal or Tribal land, 69% of which is reserved.[10]

Currently, of the 85 subbasins in the State, 70 contain claims for reserved water rights. Adjudication of water rights in these basins is complicated by factors that include: checkerboard Tribal and non-Tribal ownership of fee land within Indian reservations; private water diversions within national forests; preexisting dams within wilderness areas; rivers that form the boundaries to national parks and Indian reservations and also form the boundaries to private land; and streams that begin in areas of private land before flowing onto a reservation with reserved instream flow rights.

To mitigate impacts that reserved water rights might have on private water users, states have attempted to quantify reserved water rights. The goal is to limit future water use (by the Park Service in this case) and provide notice of the potential magnitude of future senior uses to junior water users. The Montana Water Use Act, Title 85, chapter 2, MCA, passed in 1973 and amended by Senate Bill 76 in 1979, established a state-wide general adjudication for all state-based water rights in existence before 1 July, 1973, and all federal and Indian reserved water rights.

Negotiations between the State and the National Park Service began during the early 1980s, but broke off in 1986 due to disagreement over proposed amounts of instream flows. During the spring of 1992, the Compact Commission and the Park Service resumed negotiations to settle federal reserved water rights for five National Park Service units in Montana including Yellowstone National Park, Glacier National Park, Big Hole National Battlefield, Little Bighorn Battlefield National Monument and Bighorn Canyon National Recreation Area. The National Park Service is the first federal agency to settle its reserved water rights with the Compact Commission in the State of Montana's adjudication process. Appendix A is the finalized 1993 Compact for Yellowstone, Glacier, and Big Hole, hereafter referred to as 1993 Compact. Appendix B is the finalized 1995 Compact for Little Bighorn, and Bighorn Canyon, hereafter referred to as 1995 Compact. These Compacts were incorporated as one Compact into Montana Code Annotated 85-20-401.

Members of the Commission Negotiating Team for the 1993 Compact were: former Representative Dave Wanzenried, Chairman of the Negotiating Team; Senator Lorents Grosfield; former Representative Bob Thoft, and Chris Tweeten, Chairman of the Compact Commission. Former Senator Joe Mazurek was with the Team initially. The Team negotiating the 1995 Compact included: former Representative Bob Thoft, Chairman of the Negotiating Team; Senator Lorents Grosfield; Representative Emily Swanson, and Mr. Chris Tweeten.

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[10] U.S. Department of Commerce, 1990: Table 358 at 219.

Commission staff working on the Compacts included David Amman, Hydrologist; Ariel Anderson, Soils Scientist; Craig Bacino, Geographer and GIS Specialist; Barbara Cosens, Legal Counsel; Susan Cottingham, Staff Director; Bill Greiman, Agricultural Engineer and Joan Specking, Historian and Technical Team Leader.

Negotiators for the Park Service were Mr. Owen Williams, Chief of the National Park Service Water Rights Branch, Fort Collins, Colorado; Mr. Rich Aldrich, Field Solicitor for the Department of the Interior in Montana; Mr. Eric Gould and Mr. Dave Gehlert, U.S. Department of Justice, Washington, D.C. and Mr. Jim Dubois, U.S. Department of Justice, Denver, Colorado.

After more than a year of intensive technical work by Park Service and Commission staff and more than a dozen negotiating sessions, the parties reached agreement on issues relating to Glacier National Park, Yellowstone National Park, and Big Hole National Battlefield in 1993. Negotiating sessions were open to the public and public comment was received during meetings, as well as at open houses held in West Yellowstone and Gardiner and during public meetings held in Kalispell, Wisdom, Bozeman, and Gardiner. The agreements received approval from the full Commission and in April the Compact was ratified by the 1993 Legislature and was signed by Governor Marc Racicot on May 12, 1993. The Compact was approved in February, 1994 by the U.S. Department of the Interior and the U.S. Department of Justice.

The negotiating teams decided that due to time constraints in 1993, they would finalize agreements for Little Bighorn Battlefield and Bighorn Canyon National Recreation Area in a separate Compact. Negotiations and technical work on those units resumed following the legislative session in 1993. As in previous negotiations, meetings were open to the public, and open houses were held in Lodge Grass and Billings. Because both units are located primarily within the Crow Reservation, the Commission and the Park Service held a meeting with the Crow Tribal Council to explain the Compact and to seek comments from the Tribe. The Compact was unanimously approved by the Commission in December 1994, received full approval from the Commission on December 16, 1994, was ratified by the 1995 Legislature, and was signed by the Governor on March 15, 1995, and by the Secretary of the Interior on May 30, 1995.

The Compact has been submitted to the Montana Water Court for integration into final decrees for each water basin. At this stage, individual water users who do not feel their concerns have been met and believe they have a legal basis for objection, may do so in Water Court. If the court sustains an objection, it must void the Compact, as the document may not be altered without renegotiation.

ARTICLE II : IMPLEMENTATION

Article II covers implementation of the Compact. Article II explains the manner in which consumptive uses are to be calculated to ensure compliance with instream flow quantifications, and also covers reporting requirements, enforcement and administration. These areas are detailed

below. In addition, Article II authorized the preparation of an abstract of the National Park Service Water Right. The purpose of this is to aid the Water Court and the Department of Natural Resources and Conservation in entering the water rights of the National Park Service in the State database. The Abstract has been provided to the court and to DNRC and is referenced in the Compact as Appendix 1 for Yellowstone, Glacier and Big Hole, and as Appendix 2 for Little Bighorn and Big Horn Canyon.

The following sections of Article II warrant further explanation:

> Instream flow right: Article II provides that the instream flow rights on Category 3 and 4 streams are quantified as the amount of water remaining in the streams after all rights of any agency of the United States are satisfied and all state-based rights to which the instream flow right is subordinated are satisfied. The state-based rights to which the instream flow right is subordinated are specific to the stream and are discussed below under Article III. In general, existing water rights and a specified amount of future development is protected. The approach of allocating the water remaining to instream flow rather than quantifying the instream flow right recognizes the variability in stream flow. It provides a higher level of protection to state-based rights because, even in severe drought, those rights will be satisfied first.
>
> The instream flow right covers only the stretch of the stream that either flows over or borders reserved land administered by the National Park Service. The instream flow right does not extend downstream from a Park. An instream flow right may not be changed to any other use.
>
> Calculation of Consumptive Uses: Because instream flow rights are to the water remaining in the stream after existing state-based water rights and a specified amount of future development are satisfied, Article II specifies how new development is to be accounted for.
>
>> The calculation of new consumptive use must include all permits issued on and upstream of the stretch of water designated for the instream flow rights and on all tributaries upstream of the reserved portion of the stream. The reserved portion of the stream is limited to the area where it flows over or forms the boundary to reserved land.
>>
>> The calculation of new consumptive use must include all permits and certificates to develop groundwater that is hydrologically connected to surface water that is tributary to the reserved portion of the stream. Because even small wells can have a cumulative effect on surface water flow, the wells that are exempt from the permit process must be included. To expedite processing of these applications they are subject to a simplified "registration" process. In this process only the United States may object. The United States must show that the well is

hydrologically connected to surface water. If the United States is successful and the limit on consumptive use has not been reached, the only result is that the appropriation is included in the calculation of the amount of water that can be developed. If that limit is reached, the appropriation could not proceed. For wells larger than the 35 gpm limit, the burden is on the applicant to show that it is not hydrologically connected to surface water.

Groundwater developed before January 1, 1993 is not included in the calculation of consumptive use. During negotiations the National Park Service became concerned that the publicity surrounding the draft Compact could lead to a rush to appropriate. Thus, for wells developed between January 1, 1993 and the effective date of the Compact, the National Park Service may prove that they are hydrologically connected to surface water, and therefore must be accounted in the limits on consumptive use.

Article II also provides that, for the purposes of calculating the existing level of consumptive use, water rights as finally decreed will be used. In addition, non-consumptive uses are not limited or included in the calculation of consumptive use. Finally, when the limit on consumptive use is reached the basin upstream from the reserved water right is closed to new consumptive use of surface water and to new development of groundwater that is hydrologically connected to surface water.

Reporting and Notice of Change in Use: Article II requires reciprocal reporting by DNRC and the NATIONAL PARK SERVICE of changes in use and new development. The NATIONAL PARK SERVICE must also notify water users of any proposed change in use of its right to consumptive use of water.

Enforcement: The Compact does not establish a specific procedure for enforcement, but provides that petition may be filed in a state or federal court of competent jurisdiction by the State, the United States or a water right holder.

ARTICLE III: WATER RIGHT QUANTIFICATION

Technical Overview

Commission and Park Service staff spent many hours calculating such details as flow estimates and existing water rights for the streams and rivers for the five park units. In addition, the Commission staff produced maps of each unit. The following sections outline some of the details of the Geographic Information System and hydrology work done by the Commission staff to provide the Commission with the information necessary to complete the Compact.

Geographic Information Systems

Geographic Information Systems (GIS) are an automated approach to using and producing spatial information. GIS integrates mapped features (e.g. well locations, rivers, or counties) with related information in databases (e.g. flow rates, names, population figures) within a computer. Using a GIS, one can perform geographic analyses and produce maps and reports. The Reserved Water Rights Compact Commission uses GIS to integrate large amounts of data from various sources in order to answer questions critical to negotiating reserved water rights. These data include issues such as hydrology, boundaries, water rights, land ownership and administration, irrigation, and geology. All parties in the negotiating process benefit from the information produced using a GIS.

Geographic data on stream locations, park boundaries, area landmarks, water rights, land status, and more came from a number of sources including the National Park Service, U.S. Forest Service (USFS), U.S. Geological Survey (USGS), Department of Natural Resources and Conservation (DNRC), Montana Bureau of Mines and Geology (MBMG). Data from these sources, and others, were integrated into a common format using a geographic information system (GIS). Most data were available digitally and readily integrated with automated conversion routines, but some mapped data was manually digitized by the Commission staff.

For technical analysis, some of the most important spatial data were not available in a mapped format, but rather as text or database files using legal land descriptions to locate data. Examples of this data are water rights claims from DNRC and ground water wells from MBMG. With this method, the U.S. Public Land Survey System (USPLSS) of township, range, section, and aliquot parts is used to locate point (groundwater wells) or areal data (irrigated acreage). A groundwater well may be described as being located within the northeast quarter of the southwest quarter of the northwest quarter of Section 6, Township 7 East, Range 9 South (NESWNW Sec. 6, T. 07E, R. 09S).

Data in this format is not readily mapped by computer systems because it does not utilize a coordinate system based upon a single point of origin. With the USPLSS, land is demarcated within a township into 36 sections, measured from a corner of that township as the origin. Sections are mostly regular in size and shape, one mile square, with some irregularities due to curvature of the earth's surface and surveying error.

In order to map data based on legal land descriptions several steps were taken. First, the southeast corner of each township within the study area was manually digitized from 1:100,000-scale maps. Coordinates were generated for each of these points using commercial software routines. A series of computer programs written by the Commission's computer specialist Craig Bacino used these "origins" to compute centroids for point data and parcel corners for areal data from legal land descriptions. Regularity of section size and shape is assumed by the algorithms used to calculate locations.

Irregularities in the USPLSS can result in some loss of accuracy when data is mapped. Another consideration when data is plotted from legal land descriptions is the variable level of precision inherent in describing point locations using the USPLSS. For example, a point feature can be described as being located within a quarter section (160 acres), a quarter-quarter section (40 acres), a quarter-quarter-quarter section (10 acres), and so on. Each subsequent subdivision by aliquot parts results in a higher level of precision in describing the location of the point feature.

Using these methods, maps of the five National Park units were generated for the technical staff, negotiators, and the public in order to facilitate the compact process. These maps display combinations of data themes such as land ownership, administrative boundaries, hydrography, streams by Compact categories, water rights claims by type of use and priority date, the Yellowstone Controlled Groundwater Area boundary, and irrigated lands.

Hydrology

Legal Background for Instream Flow

The primary purpose for which a reservation is established determines whether and how much water is reserved[11] The National Park System Act sets forth the "fundamental purpose" of the national parks: "to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations"[12]

The U.S. Supreme Court has not interpreted this language in the context of quantification of reserved water rights for national parks. Nevertheless, dicta by the U.S. Supreme Court suggests that the Court would associate relatively broad purposes with a national park. In addressing the scope of reserved water rights for national forests, the Court suggested that the narrow purposes for which national forests were reserved contrast sharply with the broad purposes of a national park.[13] Specifically, the Court stated that, "[a]ny doubt as to the relatively narrow purposes for which national forests were to be reserved is removed by comparing the broader language Congress used to authorize the establishment of national parks."[14]

As further support for this distinction, the Court quoted the U.S. Department of Agriculture, Report of the Forester 10-11 (1913) stating that "'[t]he aim of administration [of a national forest]

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[11] *United States v. New Mexico*, 438 U.S. 696, 700 [1978]); *Cappaert v. United States*, 426 U.S. 128, 141 [1976]; *Winters*, 207 U.S. at 577 [1908].

[12] 39 Stat. 535, §1 as amended, 16 U.S.C. §1.

[13] *New Mexico*, 438 U.S. at 709.

[14] Ibid.

is essentially different from that of a national park, in which economic use of material resources comes second to the preservation of natural conditions on aesthetic grounds'"[15]

Arguably, the broad language of the National Park System Act of 1916 merely identifies the scope of possible purposes for which parks may be established. The documents and legislative history detailing the reservation of the specific units provided clear guidelines for determining the intent of Congress.

Instream Flow Characterization and Methodologies

As explained above, because National Parks are created to "conserve the scenery and the natural and historic objects and the wildlife therein...",[16] the primary claim to reserved water is for use as instream flow. Thus, studies focussed on understanding stream flow on streams that flow through both Park and private land. Appendix I lists flow estimates for all streams included in the Compact.

Streamflow in these areas follows the snowmelt runoff regime typical of high elevation watersheds in the Northern Rockies. Flows are characterized by large seasonal fluctuations, with low flows occurring in late fall through early spring and high flows occurring in the spring and summer months. Average monthly high flows may be more than ten times larger than average monthly low flows. The seasonality of flows is caused by precipitation and temperature patterns.

Consumptive water use adjacent to the parks is also seasonal and occurs during the spring and summer high flow months. Because the streamflows and consumptive uses are seasonally distributed, accurate estimates of monthly flows are important in determining instream flow needs and evaluating future consumptive demands. Because of the variability in stream flow the Compact takes the approach of quantifying the amount of water available for consumptive use. The water remaining is the instream flow right and is not described by a specific quantification.

Most of the streams in the Compact are not gaged, so indirect methods were used to estimate average monthly flows for several streams. Equations which use channel and watershed characteristics were developed by the USGS to estimate monthly flows of ungaged streams in the Upper Missouri River Basin.[17] These equations were used to estimate flows for Big Hole and Yellowstone streams.

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[15]*New Mexico*, 438 U.S. at 709 n.16.

[16]16 U.S.C. §1.

[17]Parrett, C., Dave R. Johnson, J.A. Hull. "Estimates of Monthly Streamflow Characteristics at Selected Sites in the Upper Missouri River Basin, Montana, Base Period Water Years 1937-86." U.S. Geological Survey (Water Resources Investigations Report 89-4082), 1989.

The USGS methodology provides different equations for estimating natural monthly flow characteristics on different types of stream channels. One method uses watershed size and average annual precipitation to estimate flows. Another method is based on active channel width, and another method uses flow measurements on the ungaged stream and relates them to concurrent flow records on a nearby gaged stream. Each of the above methods (area-precipitation, active channel width, concurrent) was used on one stream or another, depending on the morphological channel characteristics and data availability.

There are many different methods for determining instream flow needs which are designed to protect a single riparian value. For example, an analysis may determine the amount of water needed to flush sediments downstream or to provide for optimal fish habitat. Several methods are statistical and may be completed with relative ease. Others may take years of field data collection and verification. A precise measurement of the flows necessary to satisfy national park purposes could be time consuming and expensive. For these negotiations, instream flow amounts were determined through flow duration estimation and a literature review of existing instream flow studies of similar streams.[18] The methods used to determine the instream flows that were eventually negotiated provide a high level of resource protection, especially when compared to other preliminary methods, such as the Tennant Method[19], or the Arkansas Method.[20] These latter methods are less refined and therefore less specific to individual streams.

WATER RIGHTS ON INDIVIDUAL NATIONAL PARK SERVICE UNITS

BIG HOLE NATIONAL BATTLEFIELD

Legal/Historical Background of the Creation of Big Hole National Battlefield/Priority Date

Big Hole National Battlefield was created by Executive Order No. 1216 on June 23, 1910 as a memorial to members of the Nez Perce Bands and the soldiers of the 7th U.S. Infantry who fought in the Big Hole Battle.[21] The 655-acre Battlefield marks the spot of the turning point in the Nez Perce War which began on June 15, 1877. Approximately 55,000 visitors tour the site

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[18] See Bibliography for more information on literature used.

[19] Tennant, D.L. "Instream Flow Regimes for Fish, Wildlife, Recreation and Related Environmental Resources." Billings: U.S. Fish and Wildlife Service, 1975, 30.

[20] Mathews, R.C. and Yixing Bao. "The Texas Method of Preliminary Instream Flow Assessment". *Rivers* 2(4) 1992, 295-310.

[21] President. Executive Order. Creating Big Hole Battlefield Monument. June 23, 1910.

each year. Land was added to the Big Hole Battlefield by Presidential Proclamation on June 29, 1939, and by Congress in 1963.[22] See Appendix C for a map of the Big Hole area.

The Battlefield carries a reserved water right for purposes defined in the 1910 and 1939 reservations. The 1910 Executive Order set aside the acreage, stating that "embracing the Big Hole Battlefield Monument in Beaverhead County, be, and the same is hereby, reserved for military purposes for use in protecting said monument...." The 1939 Presidential Proclamation added contiguous land to the Battlefield site and gave more detail regarding the purpose of the Battlefield as an historic landmark:

> Whereas, it appears that certain public lands...are historic landmarks, forming a part of the battle grounds where Chief Joseph and a band of Nez Perce Indians were defeated by a detachment of United States soldiers;
> Whereas certain other public lands...are necessary for the proper care, management, and protection of the historic landmarks included within the monument:....

Although the Battlefield was originally reserved in 1910, the Executive Order did not set out specific purposes for the reservation. Commission and the Park Service agreed that based on the 1939 Proclamation a primary purpose for reserving the Battlefield is historic interpretation. Thus they agreed to a priority date of June 9, 1939.

The Big Hole Battle took place on August 9-10, 1877, when less than 200 members of the 7th Infantry of the U.S. Army attacked a group of about 800 Nez Perce Indians who were fleeing to Canada to escape being placed on a small reservation in the United States. The Nez Perce were surprised early on the morning of August 9, 1877 while they were sleeping in their camp along the east bank of the Big Hole River. Historical sources show that the Nez Perce camp was located on a grassy plain adjacent to the confluence of Ruby and Trail creeks which come together at the site to form the North Fork of the Big Hole River. The battle took place in and around the river, and both Nez Perce and 7th Infantry soldiers fought and died while Nez Perce women and children tried to hide in the water and under the river banks.[23] Thus the parties agreed that the presence of the river is a necessary part of the historic interpretation for the Battlefield.

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[22]Presidential Proclamation, June 29, 1939 and U.S. Statute at Large 77(1963)81.

[23]See Brown, Mark H. The Flight of the Nez Perce. New York: G.P. Putnam's Sons, 1967; Josephy, Alvin M. The Nez Perce and the Opening of the Northwest. New Haven: Yale University Press, 1965; McWhorter, Lucullus V., Yellow Wolf: His Own Story. Caldwell: The Caxton Printers, Ltd., 1952; Hathaway, Ella C., Battle of the Big Hole in August, 1877, as told by T.C. Sherrill. Seattle: Shorey Book Store, Facsimile Reproduction, 1967.

Summary of Agreements

Consumptive Use

The Park Service and the Commission agreed that Park Service consumptive uses would include water for the visitor center, administrative offices, picnic area, maintenance area, residences, and irrigation within the Battlefield. The total amount agreed to is 7.14 acre feet per year. This amount is based on past water use, as well as expected visitation increases.

In addition, the agreement recognizes that the use of water for emergency fire suppression benefits the public, and that the Park Service may divert water for fire suppression at the Battlefield. Such use will not be counted as Park Service consumptive use, or be considered a violation of the instream flow right.

Instream Flow Rights - North Fork of the Big Hole River

Because a purpose of the Monument is to preserve the historic condition of the Battlefield site, the Park Service and the Commission agreed that a federal reserved water right exists for instream flow necessary to maintain the channel characteristics and riparian habitat of the North Fork of the Big Hole River. As noted above, the river and surrounding riparian vegetation was where soldiers and Nez Perce took cover during the fighting.

Stream Flow Estimates

Although some gage data exists for Trail Creek, the period of record is short and the records do not correlate well with long- term monthly averages on nearby gaged streams, such as the Big Hole River. Since the USGS equations were already used to estimate the flows of Trail and Ruby Creeks, these estimates were combined to get the average monthly flows of the North Fork at the Battlefield. The USGS estimates were based on watershed and channel characteristics of these streams.

Current consumptive use was analyzed by adding the maximum diversion rates of water rights in the Ruby and Trail Creek watersheds above the Battlefield and examining the current acreage of land being irrigated. The potential for new irrigation was assessed by evaluating the area for potentially irrigable lands not currently irrigated lands.

Existing valid state water claims upstream of the Battlefield exceed the estimated average monthly flows. However, current use does not dewater the streams because water rights holders generally practice flood irrigation. This type of irrigation helps maintain a good base flow in the streams

due to return flow contributions.[24] Also, water is not diverted over the entire growing season, but is diverted only long enough to saturate crop lands.

Quantification

The Commission and the Park Service agreed that a Park Service water right for 10 cubic feet per second (cfs) of instream flow on the North Fork of the Big Hole River from November through March would be subordinated to state water rights with a priority date prior to effective date of the Compact. The North Fork is formed by Ruby Creek and Trail Creek, therefore, the parties agreed that the instream flows granted to the Montana Fish, Wildlife and Parks for those two streams would be added together (4 cfs for Ruby Creek and 6 cfs for Trail Creek).

From April through October the Park Service will have a water right for instream flow in the amount left in the river after all existing consumptive uses with a priority date prior to the effective date of the Compact are satisfied. The existing consumptive uses are mostly upstream irrigation during the summer months. The purpose of the instream flow is to keep water in the stream during the summer to maintain vegetation and channel characteristics.

The numbers in the Compact were derived by figuring the total consumptive use that equals or exceeds 5% of the estimated average monthly flow and requiring that during those months, the North Fork Big Hole River basin will be closed to new appropriations for consumptive use upstream of the Battlefield in order to have enough water to maintain the channel and surrounding riparian vegetation. The 5% depletion is within the stream gage error, and therefore, uses to up to 5% should not impact the stream. If consumptive use reached 5% or above, depletion of the average monthly flow, riparian and channel characteristics could be affected. As noted above, the surrounding vegetation and the stream channel are important to the maintenance of the historical setting of the Battlefield. (See Article III, sec.A. (2), Table 1, MCA 85-20-401.)

The approach that was used protects the riparian value and channel characteristics year-round, whereas the channel maintenance approach would only protect certain high flows in the spring.

There are several private ditches crossing the Battlefield, therefore, it was agreed that existing rights to divert water from points within the Battlefield and transport it for use off the Battlefield will be protected by this agreement.

Groundwater

As part of the instream flow right on the North Fork of the Big Hole River, there are clauses in the Compact relating to groundwater appropriations. These provisions do not recognize a reserved water right for groundwater that is separate and distinct from that for instream flow.

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[24]Levings, J.F. Water Resources of the Big Hole Basin, Southwestern Montana. Butte: Montana Bureau of Mines and Geology (Memoir 59),1986.

Instead, they are included in the Compact in recognition of the fact that appropriation of groundwater may impact streamflow. These agreements take into consideration the effect on existing users as well as on Park Service instream flow rights.

The Commission and the Park Service agreed that new wells (those appropriated after January 1, 1993) will not be included in the limits on consumptive use unless they are hydrologically connected to surface flows tributary to the North Fork of the Big Hole River at or above the Battlefield. An applicant for a well in excess of 35 gpm will be required to submit a report prepared by a qualified professional showing that the well is not hydrologically connected to surface flow.

Groundwater appropriations upstream from the Battlefield by well or a developed spring of 35 gpm or less that do not exceed 10 acre-feet per year, i.e., those wells currently exempt from permit requirements under state law, must obtain a permit, but will not be included in the calculation of total consumptive use unless the United States shows that the proposed appropriation is hydrologically connected to surface flow. Because such uses would normally be exempt from permit requirements under state law, the Commission and the Park Service agreed to an expedited process for small wells in which only the United States may appear as an objector. There are no requirements for wells with a priority date before January 1, 1993.

The Park Service agreed to subordinate its water right to future non-consumptive uses of water even if developed after the limit on consumptive use is reached, if they do not cause a reduction in the source of supply, do not delay the return of the diverted water to the source of supply, or adversely affect the quality of the water as it enters Big Hole National Battlefield.

BIGHORN CANYON NATIONAL RECREATION AREA

Legal/Historical Background of Bighorn Canyon National Recreation Area/Priority Date

Bighorn Canyon National Recreation Area was created by an Act of Congress on October 15, 1966. The purpose of the Recreation Area is "for public outdoor recreation use and enjoyment of the proposed Yellowtail Reservoir and lands adjacent thereto...and for preservation of the scenic, scientific, and historic features contributing to public enjoyment of such lands and waters...."[25] The priority date for Park Service water rights on the Recreation Area is October 15, 1966. Please see Appendix H for a map of the Bighorn Canyon area.

Summary of Agreements

As noted previously for Little Bighorn Battlefield National Monument, the agreements between the Park Service and the Commission do not have any impact on the senior reserved water rights of the Crow Tribe.

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[25]U.S. Statutes at Large 80 (1966) 913.

Consumptive Use

The negotiating teams agreed on Park Service consumptive uses for visitor centers, resident employees, pasture irrigation, campgrounds, picnic areas, marinas, and stock and wildlife watering. The amount agreed upon is 251.5 acre feet per year. This amount is based on current use, with additional water included for management flexibility and expected increased visitation. The Park Service may also use water for fire suppression as needed. See Article III, sec. B(2), Table 3, MCA 85-20-401.

Instream Flow Rights

The instream flow rights in the Recreation Area extend to streams flowing through the area and do not extend to the mainstem of the Bighorn River or to the water impounded in Yellowtail Reservoir.

Stream Flow Estimates

None of the streams in this area are gaged. To get an idea of the flows, the streams were examined where they enter the recreation area, and where they enter Yellowtail Reservoir. Flows were estimated by both Park Service and Compact Commission hydrologists, with little or no discrepancy. In addition, several small springs were examined and flow estimates were made.

Several streams begin outside the recreation area boundary on private, national forest, and BLM lands. Because the purpose of the Recreation Area included preservation of waters, the Park Service could assert a claim to all the water. Similar to Glacier and Yellowstone, the Park Service agreed to an amount of consumptive use within the statistical error of stream flow measurements. Instead of conducting comprehensive studies of instream flow needs for these streams, the Commission negotiated an amount of water for future state use. This future use amount is equivalent to the existing level of non-irrigation use in each watershed. An analysis of potentially irrigable acreage was conducted. Commission soil scientist Ariel Anderson and agricultural engineer Bill Greiman researched existing irrigation claims on Dry Head, Deadman, Davis and Layout Creeks and concluded the claims were supported by evidence of historic irrigation with ditches, although there was no evidence of current irrigation use in those locations. This research helped establish that the amounts of water for future use as shown in the Compact are enough to provide for future uses in the watersheds. All other flow is dedicated to instream flow and wildlife use where it enters the Recreation Area. (See Art. III, sec. B (3)(b)(ii), Table 4, MCA 85-20-401.)

Trail Creek watershed, including the North and South forks, is almost completely contained within the recreation area. Since there are no private uses within this drainage, all the flow is dedicated to the Park Service for instream flow and wildlife use.

The Park Service also claimed small amounts of instream flow for two streams which originate as springs outside the recreation area: Pete's Spring and Annerer Spring. The Park Service holds a state water right for half the flow of Pete's Spring, and received an instream flow of 1 gpm for Annerer Spring. In July, 1994, Annerer Spring was flowing between one and three gpm, which was assumed to be baseflow, considering the drought conditions that year.

Stream Categories

In determining instream flow rights for streams in the recreation area, as done with previous Park Service units, the negotiators divided the watersheds into categories based on current land and water use.

Stream category 1a includes streams which are contained within the park, and drain only federal lands. These streams are the North and South forks of Trail Creek, and Trail Creek. All water in these streams, minus Park Service consumptive uses, is dedicated to instream flow.

Category 3 streams are those which begin outside the recreation area and drain private lands before entering the recreation area.

These streams include Dry Head Creek, Deadman Creek, Davis Creek (also known as Medicine Creek), and Layout Creek. The negotiators agreed on allowing some level of future consumptive use in each of these watersheds. These amounts are roughly twice the existing use in each watershed. Again, see Table 4 of the Compact.

The special case, or category 4, streams for Bighorn Canyon, are the streams issuing from Pete's Spring and Annerer Spring. The Park Service holds a previously acquired water right for one-half the flow from Pete's Spring. Instead of negotiating a new right for this stream, the Park Service will retain this state-based water right. On the spring formed from Annerer Spring, the Park Service will maintain an instream flow of one gpm, mainly for wildlife use. Both of these springs originate outside the recreation area boundary and the Park Service instream flow rights take effect at the boundary, where the streams flow in.

In addition, the negotiators agreed that the Park Service would receive water rights for all of the flow of springs and seeps occurring within the recreation area boundaries.

Groundwater, Impoundments, Non-consumptive Uses

Existing groundwater uses are protected by the Compact, and are exempt from a call by the Park Service. Additionally, small groundwater uses (less than 35 gpm and 10 acre feet per year) may be developed for domestic and stock watering purposes, unless the U.S. shows by a preponderance of evidence that the proposed appropriation is hydrologically connected to surface water of a Category 3 or 4 stream.

GLACIER NATIONAL PARK

Legal/Historical Background of Glacier National Park/Priority Date

One million acres in size, Glacier National Park is visited by over 2 million people each year. Due to the spectacular mountainous scenery in the area, the park was reserved by an Act of Congress on May 11, 1910, "as a public park or pleasure ground for the benefit and enjoyment of the people of the United States."[26] Glacier National Park was reserved out of land in the Lewis and Clark Forest Reserve created by President Cleveland on 22 February, 1897,[27] as superseded by a 1903 Presidential Proclamation,[28] and includes land east of the continental divide ceded by the Blackfeet Tribe in 1896.[29]

Similar to the language reserving Yellowstone National Park, the quoted language does little to reveal the intent of Congress. The administration section provides further evidence by directing the Secretary to make regulations to "provide for the preservation of the park in a state of nature so far as is consistent with the purposes of this Act, and for the care and protection of the fish and game within the boundaries thereof".[30]

The legislative history indicates many references to Glacier's unique location on the triple divide between the headwaters of the Missouri, Columbia, and Hudson rivers, and the need to protect the park's fish and game. For example, the Senate Report accompanying the second introduction of the bill to the Senate to reserve Glacier National Park states that

> [t]he park will embrace about forty glaciers and a large number of lakes and streams. From this area water flows to the Hudson Bay, Gulf of Mexico, and the Pacific Ocean. The mountain scenery is of unparalleled grandeur and beauty...

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[26]U.S. Statutes at Large 36 (1910)354.

[27]Presidential Proclamation No. 31, U.S. Statutes at Large 29(1897)911.

[28]Presidential Proclamation No. 3, U.S. Statutes at Large 33 (1903)2311.

[29]U.S. Statutes at Large 29(1896)353-358.

[30]U.S. Statutes at Large 36 (1910)355.

> Lake McDonald, near the southwestern boundary of the proposed park, is a sheet of water of an unmatched beauty . . .. [31]

The Commission and the Park Service agreed that the priority date for Glacier National Park is May 11, 1910. See Appendix D for a map of the Glacier National Park area.

Summary of Agreements

Consumptive Use

The Park Service and the Commission agreed on Park Service consumptive uses which include water for park administrative and domestic uses, park concessions, maintenance sites, ranger stations, campgrounds, lodges, and other places of use within Glacier National Park. The total amount agreed to is 567.8 acre-feet per year. The amount is based on current water use, and additional water to allow for future management flexibility and response to increased visitation. The Park Service may divert water for fire suppression as necessary. See Art. III, sec. C(2), Table 5, MCA 85-20-401.)

Instream Flow Rights

Stream Categories

In order to more easily address the issues involving reserved water rights for Glacier National Park , the negotiators broke the watersheds into categories based on the types of streams involved, as illustrated in Appendix D. The same categories would be used for the other Park Service units as necessary.

Category 1 includes all streams that begin in the park and flow directly out. These streams are dedicated to instream flow, minus any Park Service consumptive use claims. No private claims exist on these streams.

Prior to the 1910 reservation of Glacier National Park, certain land within the area that was to become the Park had been patented by private parties. To protect the pre-existing rights of these landowners, category 1a includes all streams that begin in the park and flow out through non-federal land within the Park. The water in these streams is dedicated to instream flow after existing private water rights within the Park are satisfied.

Categories 2 and 3 were established for Yellowstone National Park to include all streams that headwater in the State of Montana outside of the Park and flow into the Park. There are no category 2 or 3 streams associated with Glacier National Park.

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[31] S. Rep. No. 106, January 20, 1910, [quoting S. Rep. 580, April 29, 1908, the Report accompanying the first introduction of a bill to reserve Glacier].

Category 4 streams are special case streams requiring individual treatment for quantification. They include the North Fork and Middle Fork of the Flathead River, which form the south and west boundaries to the Park; Rubideau Creek, which is fed by a spring diverted for use outside the Park by the Community of West Glacier; and Divide, Jule, and Wild Creeks, reaches of which are shared by the Park and the Blackfeet Reservation.

Stream Flow Estimates

The streams at issue are the rivers that form the west and south boundaries of the park. These boundary streams are the North Fork and Middle Fork of the Flathead River.

Average monthly flows for these rivers were calculated from long-term stream gage data. The USGS gaging stations are located near the confluence of the two rivers, where they cease to form the boundaries of the Park. The gages have been operated for over 50 years and give an excellent approximation of the flow characteristics.

Due to the preservation purposes of Glacier National Park that include "care and protection of fish and game within the boundaries...," the parties agreed that a federal reserved water right exists for instream flow to keep water flowing in the streams as necessary to protect the resources "in a state of nature..."[32] The North Fork and the Middle Fork of the Flathead River are important elements of the ecosystem within the Park. Resident wildlife in these basins includes threatened species, such as the bull trout and grizzly bear. A report completed in 1982 by the Montana Department of Fish, Wildlife and Parks details the types and abundance of the local wildlife and quantifies the amount of water needed as instream flow to protect and provide for a healthy ecosystem.[33] There are several months in which the report recommends that almost all water remain instream.

Another report details the status of the threatened bull trout in the Flathead River system, and confirms the need for careful management of riparian resources to prevent extinction of the species.[34] Both bull trout and cutthroat trout inhabit these rivers and are highly sensitive to environmental conditions.

Due to the clear Congressional intent to reserve Glacier National Park for preservation of fish and wildlife habitat and the available studies indicating that very little diversion from the rivers would

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[32]U.S. Statutes at Large 36 (1910)354.

[33]Montana Department of Fish, Wildlife and Parks. "Instream Flow Evaluation For Selected Waterways in Western Montana." Helena: Ecological Services and Fisheries Divisions, 1981.

[34]Thomas, G. "Status Report: Bull Trout in Montana." Prepared for Montana Department of Fish, Wildlife and Parks, Helena, 1992.

be acceptable, the Park Service originally sought the entire flow. However, the Park Service offered to protect existing and some future use if it was within the statistical range of measurable depletions. Because of the high flows in these rivers, this set the stage for agreement. (See Appendix I for the mean monthly flows of the North and Middle Forks of the Flathead River.) Because of the low level of consumptive use in these basins and low future use projections, the state agreed to an amount of water which will allow future use of no more than double the estimated existing use. The resulting instream flow agreed to in the stretch of these rivers bordering the Park ranges from 95 to 99 percent of estimated average monthly flows.
In order to determine what amount of water to set aside for future uses in the basin, the Commission looked at existing water rights on record, what the current amount of land use along the rivers was, at the limited amount of private land, and what the potential could be if all the land was developed. A study done by the Flathead Basin Commission regarding development in the basin was consulted,[35] as well as input from a local land use planning group including the Flathead Basin Commission North Fork Steering Committee which includes private landowner groups in the North Fork area, federal, state and local government managers, and conservation and industry representatives.

Quantification

To quantify the water right on the North Fork and Middle Fork, the Commission and the Park Service negotiated a level of private use on streams shared by Glacier National Park and private landowners that would not impact park purposes. The instream flow right is to the water remaining after those rights are satisfied and the Park Service instream flow right is subordinate to the above level of use. The result leads to protection for all existing water rights as finally decreed by the Water Court, and identification of an additional quantity of water for future consumptive use.

The amount allowed for future use listed by month in the Table 6 of the Compact for private, state-based uses, was calculated by taking 1% of the average monthly flow for most months. (See Art. III, C(3)(c)(ii), Table 6, MCA 85-20-401.) In high flow months, however, the amount allowed for new future use is an amount equivalent to the existing use claims. This means that maximum existing and future uses on the reserved portion of the rivers will never be more than two times the current (1993) use and in most months it will be less than two times existing uses. Commission staff looked at existing water rights records in the basin and calculated the existing uses by month in order to determine what existing uses were by month. To estimate future use, either 1% of the average monthly flow or an amount equivalent to existing use, or whichever is less, was calculated. The 1% figure is within stream flow gage error. Water use on streams that contribute to the flow of the North and Middle Fork where they border the Park is included in this total. Even though they do not actually flow within the Park, and the reserved right itself does

[35]Flathead River International Study Board. Water Uses Committee. "Water and Associated Socio-Economic Activities in the Flathead River Basin of Southeast British Columbia and Northern Montana." Bozeman: Color World Printers, December, 1987.

not extend to these streams, uses on these streams affect flow in the reserved portion of the rivers. Once the total allowable amount of future use has been reached, no additional consumptive water permits will be issued.

Divide, Jule and Wild Creeks will be dedicated to instream flow minus Park Service consumptive use rights. These streams border the Blackfeet Reservation on the eastern boundary of Glacier National Park. The Park Service instream flow rights are junior to any Tribal water right or individual Indian or non-Indian water right derived from a Tribal water right. In addition, any existing water right appropriated pursuant to State law on Divide Creek is protected. On Rubideau Creek, existing claims are protected.

The agreement also recognizes the right of the Park Service to maintain natural lake levels within Glacier National Park, minus Park Service consumptive uses and other valid State water rights.

Groundwater and Impoundments

As part of the instream flow rights, there are clauses in the Compact relating to groundwater appropriations and impoundments. As explained in the section on the Big Hole Battlefield, these provisions do not recognize a reserved water right for groundwater that is separate and distinct from that for instream flow. Instead, they are included in the Compact in recognition of the fact that appropriation of groundwater may impact streamflow. These agreements take into consideration the affect on existing users and on Park Service instream flow rights.

The Commission and the Park Service agreed that new wells (appropriated after January 1, 1993) will not be included in the limits on future consumptive use unless they are hydrologically connected to surface flows tributary to the North Fork and Middle Fork of the Flathead River. An applicant for a well in excess of 35 gpm will be required to submit a report prepared by a qualified professional showing that the well is not hydrologically connected to surface flow.

Groundwater appropriations upstream from any part of the reserved portion of the rivers by well or a developed spring of 35 gpm or less that do not exceed 10 acre-feet per year, i.e., those wells currently exempt from permit requirements under state law, must obtain a permit but will not be included in the calculation of total consumptive use unless the United States shows that the proposed well is hydrologically connected to surface flow. Because such uses would normally be exempt from permit requirements under state law, the Commission and the Park Service agreed to an expedited process for small wells in which only the United States may appear as an objector. There are no requirements for wells with a priority date before January 1, 1993.

Due to the impacts of impoundments on a natural flow regime, the negotiators agreed that no new impoundments will be permitted after the date of the Compact on the mainstem of Category 4 streams where they border or lie upstream of the Park. However, existing impoundments may be repaired or rehabilitated providing the repairs do not cause the impoundment to exceed its original

capacity. This prohibition would not apply to impoundments approved through settlement of a Tribal reserved water right.

As with the Big Hole Battlefield, the Park Service agreed to subordinate its water right to future non-consumptive water uses, even those developed after the limit on consumptive use is reached, if they do not cause a reduction in the source of supply, do not delay the return of the diverted water to the source of supply or adversely affect the quality of the water as it enters Glacier National Park.

LITTLE BIGHORN BATTLEFIELD NATIONAL MONUMENT

Legal/Historical Background of Little Bighorn Battlefield National Monument/Priority Date

The Battle of the Little Bighorn took place on June 25, 1876, when General George Armstrong Custer led the 7th Cavalry to attack a large gathering of Lakota and Cheyenne camped along the west side of the Little Bighorn River. On a hill on the east side of the river, Custer, and five companies of the 7th Cavalry were killed to the last man, as well as a number of Indians.[36] Please see Appendix G for map of the Little Bighorn area.

The parties agreed that the Little Bighorn River played an important historical role in the interpretation of the Little Bighorn Battlefield National Monument, and that a water right for instream flow is necessary for the historic purposes of the Battlefield.

The priority date for Park Service consumptive uses is December 7, 1886, the year the National Cemetery was created by the President of the United States, because the small consumptive use associated with the visitors center is consistent with the purposes of a National Cemetary. This was not chosen by the parties as the instream flow date because the Act creating the National Cemetery described its purposes as being "...duly set apart by the Executive for Military purposes in connection with the Post of Fort Custer, M.T.... "[37] In other words, at that point the National Cemetery was apparently not set apart with an historical purpose in mind.

The priority date for Park Service instream flow is March 22, 1946, the date the Custer Battlefield National Cemetery was designated Custer Battlefield National Monument, "...under which name

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[36]Scott, Douglas D., et al Archaeological Perspectives on the Battle of the Little Bighorn. Norman: University of Oklahoma Press, 1989, at 15-21; and Annual Report of the Secretary of War, Report of Lieutenant General P.H. Sheridan, Vol., 1876.

[37]President. Executive Order. December 7, 1886.

this national monument shall be entitled to receive and to use all moneys heretofore or hereafter appropriated for the Custer Battlefield National Cemetery."[38] Thus, Congress broadened the purpose of the National Cemetery area to include a purpose for historical interpretation for the National Monument. The parties agreed on the importance of protecting the riparian area and surrounding vegetation as being important to protecting the integrity of the historic interpretation of the Battlefield.

On December 10, 1991, Custer Battlefield National Monument was renamed Little Bighorn Battlefield National Monument.[39]

Summary of Agreements

Because the two Park Service units are located within almost entirely within the boundaries of the Crow Reservation, the Commission and the Park Service negotiating teams sought comment and information from the Crow Tribe during the initial stages of negotiations. The Commission received a letter from Crow Tribal Madam Chairman, Clara Nomee stating that the Crow Nation has no objection to the negotiations with the understanding that Crow water rights are not affected.[40] The Compact states that the State and the Park Service recognize the seniority of the Crow Tribe's reserved water rights and of rights derived from Crow Tribal rights. This includes reserved water rights of the Tribe that are not yet developed. In addition, any administration by the State to enforce the Park Service right is limited to new water uses obtained by permit application to the State and may also be limited by any future determination of Crow jurisdiction over water rights on the Reservation.

<u>Consumptive Use</u>

The negotiating teams agreed on Park Service consumptive uses which include visitor use, irrigation of park grounds, and resident staff use. The amount agreed upon is 84.9 acre feet per year and is based on current use, with additional water included for expected visitation increases. The Park Service may also use water for fire suppression as needed. See Art. III, sec. E(2)(a), Table 7, MCA 85-20-401.)

<u>Instream Flow Rights</u>

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[38]U.S. Statutes at Large 60 (1946) 59.

[39]U.S. Statutes at Large 105 (1991)1631.

[40]Crow Tribal Council Madam Chairman Clara Nomee to Chairman of the Montana Reserved Water Rights Compact Commission, Chris D. Tweeten, November 21, 1994, Commission Files.

To protect the Little Bighorn River channel, the Park Service has a reserved water right for instream flow. There are two components to this right: a minimum flow of 51 cfs throughout the year, and a channel maintenance flow of 950 cfs for fifteen consecutive days during May or June. The minimum flow will prevent vegetative encroachment of the channel, and the high flow will flush sediments and maintain the channel thalweg (deepest part of the channel). Both flows are subordinated to existing water rights, as of the date of the Compact.

The 15-day high flow right of 950 cfs is triggered by the first occurrence of flows in excess of 950 cfs at the Battlefield in May or June. During the 15 days, junior water users (users who filed for permits after the effective date of the Compact) may be curtailed if flows drop below 950 cfs, and it is determined that 950 cfs could be reached by shutting off those junior uses. If flows do not reach 950 cfs during May or June, there will be no call on junior uses. Similarly, if flows are greater than 950 cfs, there will be no call. The call must end on June 320 even if less than 15 days have passed.

As part of the agreement, the Park Service is required to install and maintain a gaging device at the Battlefield. The gage will be calibrated at least once every three years, or as needed to maintain accuracy.

Stream Flow Estimates

There are a number of gaging stations on the Little Bighorn River in Montana. A USGS station was operated near the battlefield for several years, then discontinued. The data from this station (No. 62935-00, Little Bighorn River near Crow Agency), and the active station at Hardin, were used to calculate monthly average flows at the battlefield. Linear regression between the two stations was used to fill in missing data from the discontinued gage.

The minimum flow was determined by taking an instantaneous flow measurement, surveying the channel cross-section and water level, and calculating a Manning coefficient for the channel. The coefficient was then used to estimate the flow at a water level sufficient to cover a representative riffle section of the channel. Appendix J is a technical description of the procedure.

The high flow of 950 cfs was calculated in the same way, except that the Manning coefficient was used to estimate the flow at bankfull stage. Upon examining flow frequencies for this river, it was determined that this bankfull flow of 950 cfs occurs approximately every 1.3 years.

The duration of the flow, 15 days, was calculated as a means of protecting about 50% of the days during which 950 cfs was equaled or exceeded throughout the period of record.

Groundwater, Impoundments, Non-consumptive Uses

Existing groundwater uses are protected by the Compact, and are exempt from a call by the Park Service. Additionally, small junior groundwater uses (less than 35 gpm and 10 acre feet per year)

for domestic and stock watering purposes are protected. Groundwater uses developed within the Parkman Sandstone, Quaternary alluvium, or Quaternary Terrace Deposits and shown to be hydrologically connected to surface water by the Park Service are subject to curtailment to satisfy the Park Service reserved water right for the 950 cfs instream flow. New ground water development of greater than 35 gpm or 10 acre feet per year is subject to curtailment to satisfy the 51 cfs reserved water right if the park Service shows it is hydrologically connected to surface water.

Due to the impact of impoundments on a natural flow regime, the Commission and the Park Service agreed that new impoundments will not be permitted after the date of the Compact on the mainstem of the Little Bighorn River unless for the purpose of storing a Tribal water right or to implement the settlement of a Tribal water right. Existing impoundments may be repaired or rehabilitated providing the repairs do not cause the impoundment to exceed its original capacity.

The Park Service agreed to subordinate its water right to future non-consumptive uses of water if they do not cause a reduction in the source of supply, do not delay the return of the diverted water to the source of supply or adversely affect water quality.

YELLOWSTONE NATIONAL PARK

Legal/Historical Background of Yellowstone National Park/Priority Date

Yellowstone National Park was created as the world's first national park by an Act of Congress on March 1, 1872.[41]

The park contains more than 3,300 square miles of land, most of which is in Wyoming. In September of 1869, a group from Montana explored part of the region and made it known that some of the most intense geyser activity in the world was located in the area. Other expeditions led to increased public interest in the area. The park contains approximately 10,000 hydrothermal features, including 3,000 geysers and hot springs, and abundant wildlife including bison, elk, deer, moose and bear roam the area. Each year, approximately 2.9 million people visit Yellowstone National Park.

In creating Yellowstone National Park, Congress stated that the Park "...is hereby reserved and withdrawn from settlement, occupancy, or sale under the laws of the United States, and dedicated and set apart as a public park or pleasuring-ground for the benefit and enjoyment of the people".[42] Unfortunately, this language does not provide answers to what sort of "public park or pleasuring ground" Congress intended.

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[41] U.S. Statutes at Large 17 (1872)32.

[42] Ibid.

Section 2 of the 1872 Act governs the manner in which the Park is to be administered. It does not contain language of reservation. Nevertheless, since administration must be consistent with Park purposes, the details in Section 2 shed some light on the meaning of "public park or pleasuring ground." Section 2 directs the Secretary of the Interior to make regulations to "provide for the preservation, from injury or spoliation, of all timber, mineral deposits, natural curiosities, or wonders within said park, and their retention in their natural condition."[43]

Statements made in the Senate on introduction of the bill establishing the Park (S. 392), shed further light on the intent of Congress. On introduction, Senator Pomeroy stated

> It has been ascertained within the last year or two that there are very valuable reservations at the headwaters of the Yellowstone, and it is thought they ought to be set apart for public purposes rather than to have private preemption or homestead claims attached to them. There are valuable hot springs, geysers... [44]

Although public land in Montana was added to Yellowstone National Park in 1926, 1929, and 1932,[45] all streams that include private use upstream of the Park ultimately contribute to instream flow in the original 1872 reservation. Thus for simplicity, the Commission and the Park Service agreed that the Park has a priority date of March 1, 1872. Please see Appendix E for a map of the Yellowstone area.

Summary of Agreements

Consumptive Use

The Park Service and the Commission agreed on Park Service consumptive uses, which include water for park administrative and domestic uses, concessions, maintenance sites, visitor centers, lodges, entrance stations, back country patrol cabins, day use areas, and other places of use within the Montana portion of Yellowstone National Park. The total amount agreed to is 174.9 acre feet per year. This amount is based on past water use, with a margin of future use to allow for management flexibility and increased visitation. The Park Service may divert water for fire suppression. (See Art. III, sec. G(2), Table 8 MCA 85-20-401.)

Instream Flow Rights

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[43]U.S. Statutes at Large 17 (1872)33.

[44]The Congressional Globe, Part 1, 2d Sess. 42d Cong. at 159, 18 December, 1871.

[45]U.S. Statutes at Large 44(1926)655; 45 (1929)1435; 47 (1932)2537.

The preservation purposes of Yellowstone National Park, including "all timber, mineral deposits, natural curiosities, or wonders within said park,"[46] mean that a federal reserved water right exists for instream flow. This instream flow right keeps water in the streams to protect park resources as required by the founding Act.

Stream Categories

To more easily address the issues involving reserved water rights for Yellowstone, the negotiators separated the watersheds into categories based on the types of streams existing in and around the park. All the streams described below are listed in the Compact (MCA 85-20-401).

Category 1 includes all streams that begin in the park and flow directly out. After subtracting the Park Service consumptive use, the remainder of flow in these streams where they occur within the Park is dedicated to instream flow. No private claims exist on these streams. The reserved water right ends at the Park boundary.

Category 2 includes all streams with no private claims or private land, which begin in and flow out of wilderness areas directly into the park. After subtracting Park Service consumptive use and U.S. Forest Service consumptive use, the water remaining in these streams is dedicated to instream flow. The water right begins at the Park boundary and ends if the stream flows out of the Park. If Congress removes the Wilderness status of the areas outside the park, it is possible that these streams may be reclassified in the appropriate category on request of the state.

Category 3 includes streams that begin in Montana and flow into Yellowstone Park. The water in these streams, minus the sum of Park Service and U.S. Forest Service consumptive uses, existing water rights and a designated amount of future use is for instream flow. The water right begins where the stream enters the Park and ends if the stream exits the Park. The instream flow right is subordinate to current and future private consumptive uses up to the monthly amounts listed in the Compact which is based on 5% of the average monthly flow. As with the rivers bordering Glacier National Park, this amount is within the statistical error in stream flow measurements. Additional protections for instream flow during years of less than normal precipitation are as follows:

- The Park Service has a right to maintain a critical level of flow in the streams at the point where they enter Yellowstone National Park. This is necessary to maintain riparian habitat, including riffle areas which are primary production zones for macro-invertebrates which are primary food sources for fish. Flow measurements would be taken at the Park boundary. The right is subordinate to existing state-based uses (as ultimately decreed by the Water Court) as of December 31, 1992 and to any non-consumptive uses such as those for the Department of Fish, Wildlife and Parks. (See Art. III, sec. G(3)c)(ii), Table 9, MCA 85-20-401.)

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[46]See footnote 14.

Category 4 streams are treated individually due to special circumstances. In Yellowstone National Park these streams include the Gallatin, Madison and Yellowstone Rivers, portions of which form the boundary to the Park, and Soda Butte Creek where the existing level of consumptive water rights claims exceed the monthly amount for consumptive use. The individual protections on these streams are as follows:

▪On the Gallatin River, all the flow minus Park Service consumptive uses, U.S. Forest Service consumptive uses, existing water rights, and a designated amount of future use will be dedicated to instream flow. The instream flow right will be subordinate to existing and future non-federal uses in the amount listed in the Compact for each month.

▪The Madison and Yellowstone Rivers are gaged streams. The flows of these rivers, less Park Service consumptive uses, U.S. Forest Service consumptive uses, existing water rights and a designated amount of future use will be dedicated to instream flow. The instream flow right will be subordinate to existing and future non-federal uses in the amount listed in the Compact which was arrived at by calculating 5% of the average monthly flow. (See Art. III, sec. G(3)(d)(ii), Table 13, MCA 85-20-401.)

▪On Soda Butte Creek, instream flow will be the flow remaining after satisfying Park Service consumptive uses, U.S. Forest Service consumptive uses, existing water rights and a designated amount of future use. The Park Service has a water right for instream flow in the amount left in the river after all existing consumptive uses are satisfied. If in any month the total existing consumptive use equals or exceeds the amount listed in the Compact for each month, the Park Service instream flow right will be subordinate to those current uses.

As with category 3 streams, the parties have agreed that during periods of less than normal flow the Park Service has a reserved right to maintain a critical flow level at the point Soda Butte Creek enters Yellowstone National Park. This flow will be subordinate to any domestic use of less than 35 gpm with a priority date before January 1, 1993; to any municipal right recognized under state law with a priority date before January 1, 1993; to any groundwater use with a priority date before January 1, 1993, and to any non-consumptive use. The critical flow level is listed for each month in the Compact and was calculated by taking the average monthly flow minus 5%. The Park Service felt they could allow 5% of use and since it is within the stream gage error the effects would probably not be measurable. When flows in Soda Butte Creek fall below this level, junior non-federal water uses will be curtailed in order of reverse priority until the critical level is met. (See Art. III. sec. G(3)(d)(i)(3) Table 12, MCA 85-20-401.)

The Park Service expressed concern that alterations in natural mineral and temperature contributions to flow may impact biotic communities. The State of Montana agreed to grant the United States a water right to the natural flow from Bear Creek Hot Springs, which contribute to the Yellowstone River. There were no conflicting claims to the use of these springs and the

agreement was considered an appropriate trade for some of the protections for existing water rights.

In addition to the above clauses, the agreement recognizes the right of the Park Service to maintain natural lake levels in lakes within Yellowstone National Park, minus Park Service consumptive uses.

Stream Flow Estimates

Few of the streams in this area are gaged, so the equations developed by the USGS for the Upper Missouri River Basin were used to estimate average monthly flows. The equations were tested for accuracy by comparing known monthly averages of gaged streams in Yellowstone Park (Lamar River, Blacktail Deer Creek, Tower Creek) against monthly averages predicted by the equations. The predicted averages very closely resemble the known averages of Yellowstone streams.

Field investigation of the streams revealed that not all channels were suited to the same estimation technique. For example, Soda Butte Creek is a braided, meandering channel which runs through large (cobble and boulder) substrate. According to the USGS methodology, flow characteristics of this channel type should not be estimated by the active channel width method. Since there were a few spot flow measurements, the Concurrent Method was used.

The Gallatin River is also an ungaged, meandering, braided stream where it borders the Park. Although there is a gage 60 miles downstream, it was felt that a more accurate estimate of the discharge at the Park boundary would be calculated by using area-precipitation equations.

The active channel width method and the area-precipitation method were used to estimate the flow characteristics of the remainder of the ungaged streams.

The Yellowstone and Madison Rivers are gaged, and long-term averages were calculated from the flow records.

<u>Groundwater and Impoundments</u>

As part of the instream flow rights, there are clauses in the Compact relating to groundwater appropriations and impoundments. As explained in the sections on Big Hole Battlefield and Glacier National Park, these provisions do not recognize a reserved water right for groundwater that is separate and distinct from that for instream flow. Instead, they are included in the Compact in recognition of the fact that appropriation of groundwater may impact streamflow. These agreements take into consideration the effect on existing users and on Park Service instream flow rights.

The Commission and the Park Service agreed that new wells in basins upstream from a reserved portion of a stream (and appropriated after January 1, 1993) will not be included in the limits on consumptive use unless they are hydrologically connected to surface flows tributary to streams which flow into, or border the park. An applicant for a well in excess of 35 gpm will be required to submit a report prepared by a qualified professional showing that the well is not hydrologically connected to surface flow.

Groundwater appropriations by well or a developed spring of 35 gpm or less that do not exceed 10 acre-feet per year, i.e., those wells currently exempt from permit requirements under state law, must register but will not be included in the calculation of total consumptive use unless the United States shows that the proposed appropriation is hydrologically connected to surface flow. Because such uses would normally be exempt from permit requirements under state law, the Commission and the Park Service agreed to an expedited process for small wells in which only the United States may appear as an objector. There are no requirements for wells with a priority date before January 1, 1993.

Due to the impact of impoundments on a natural flow regime, the Commission and the Park Service agreed that new impoundments will not be permitted after the date of the Compact on the mainstems of category 3 and 4 streams. Impoundments in place as of December 31, 1992 are protected but may be called on Soda Butte Creek in dry years by the United States' critical flow right. Existing impoundments may be repaired or rehabilitated providing the repairs do not cause the impoundment to exceed its original capacity.

The Park Service agreed to subordinate its water right to future non-consumptive uses of water even after the limits on consumptive use are reached if they do not cause a reduction in the source of supply, do not delay the return of the diverted water to the source of supply or adversely affect the quality of the water as it enters Yellowstone National Park.

ARTICLE IV: YELLOWSTONE CONTROLLED GROUNDWATER AREA

Legal/Historical Background of Yellowstone Controlled Groundwater Area

The most difficult aspect of negotiations was brought on by the Park Service's assertion of a reserved water right in the amount necessary to protect the hydrothermal features of Yellowstone National Park. The parties had no difficulty in agreeing to the existence of a reserved water right to protect the hydrothermal system at the Park. Although courts in other states and the Commission have refused to recognize a federal reserved water right to groundwater when asserted merely as an incident of reservation of the overlying land,[47] the U.S. Supreme Court has

[47] See e.g., *In re the General Adjudication of all Rights to Use Water in the Big Horn River System*, 753 P.2d 76, 100 [Wyo. 1988].

held that withdrawal of water from a well may be enjoined when it impacts water reserved for the specific purpose of the reservation.[48]

The legislative history of the establishment of Yellowstone National Park indicates that one of the primary purposes in the reservation of the Park was to preserve the numerous geysers, hot springs, and other thermal features within the boundaries of the Park.[49] These features are surface manifestations of the hydrothermal system, or systems. In addition to heat, experts agreed that groundwater is an essential component of that system.[50]

Despite the United States' claim to a reserved water right for the hydrothermal features, it was apparent that quantification would be impossible. Earlier settlements of the reserved water rights for Yellowstone National Park, with Idaho and Wyoming, did not deny the right of the U.S. to seek an injunction, but declined to quantify this reserved right.[51]

The difficulty in quantification also became apparent in testimony before Congress concerning the impact of potential geothermal development on the Park, when, in 1988, Congress amended the Geothermal Steam Act.[52] The amendment authorized a study to determine the potential effects of geothermal development within the Corwin Springs Known Geothermal Resource Area (KGRA), adjacent to the northern boundary of the Park in Montana, on the thermal features within Yellowstone National Park.[53] The amendment also placed a moratorium on production of geothermal resources in the KGRA until 180 days after receipt of the study by Congress, which was to be transmitted to Congress by December 1, 1990.

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[48]*Cappaert*, 426 U.S. at 143.

[49]See The Congressional Globe, Part 1, 2d Sess. 42d Cong. at 159, 18 December 1872, and 520, 23 January 1872.

[50]Custer, S.G., D.E. Michels, W. Sill, J.L. Sonderegger, W. Weight, and W. Woessner. Unabridged recommended boundary for controlled groundwater area in Montana near Yellowstone National Park. Report to Water Resources Division. Fort Collins: National Park Service, 1993.

[51]*In re: the General Adjudication of all Rights to use Water in the Big Horn River System*, Partial Interlocutory Decree Covering the United States Non-Indian Claims [Fifth Judicial Dist., Wyo. Civil No. 4993] at 92; *Water Rights Agreement Between the State of Idaho and the United States for Yellowstone National Park*, at 17.

[52]U.S. Code. Vol. 30 § 1001(1988) et seq.

[53]Public Law 100-443, Section 8 (1988).

The USGS report concluded that substantial development of hydrothermal waters outside of the park could result in decreased discharge of thermal springs in Yellowstone, specifically in the Mammoth Hot Springs area.[54] The report provided a recommendation for limits on hydrothermal development in the Gardiner/Corwin Springs area.

On 31 October, 1991, Dr. Irving Friedman, a geochemist with the USGS testified before the Subcommittee on Mining and Natural Resources of the House Committee on Interior and Insular Affairs and objected to the conclusions of his colleagues at the USGS. Dr. Friedman testified that the data reported in the USGS study was, in his opinion, inconclusive and erred in asserting an absence of a connection between thermal features in the Park and hydrothermal water in the KGRA. Dr. Friedman further testified that data from monitoring could not distinguish impacts of geothermal production from natural fluctuations in the hydrothermal system. He concluded that it could not be stated with certainty that development outside the Park would impact the hydrothermal features within the Park.

The difficulty in identifying the source of water surfacing at hot springs and geysers demonstrates that quantification of the reservoir is not possible using our current understanding of the system. Why then, did Montana choose to settle the Park's reserved water right to groundwater for the Yellowstone Park hydrothermal system?

The answer is found in Congress's 1991 consideration of a ban on the development of geothermal resources within fifteen miles of Yellowstone National Park. That bill died in the Senate over the issue of whether the shut down of an existing well would be a compensable taking. Montana Congressman Williams vowed to continue his efforts to protect the Park's hydrothermal resources.

Concerned with the loss of local control over the use of resources associated with private and State land located outside the Park, the Commission felt it necessary to address the groundwater issue in the context of the reserved water rights settlement. In doing so, they sought a regulatory scheme that would (1) be consistent with existing State law with State oversight of water use on private land; (2) provide for the possibility of hot water development if methods are developed and/or proof provided that it can be done without impact to the Park; (3) provide a process for evaluation and modification of the boundary and restrictions as new scientific information becomes available; and (4) place decision making concerning the impact of development, and the validity of restrictions within a scientific, as opposed to political, arena, while protecting private citizens by retaining judicial review of decisions.

Montana law provided the framework necessary to accomplish these goals. Existing law allows the formation of a controlled groundwater area in a groundwater basin in which there are

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[54]Sorey, M.L., editor. Effects of potential geothermal development in the Corwin Springs Geothermal Resource Area, Montana, on the thermal features of Yellowstone National Park. Water Resources Investigations Report 91-4052. Menlo Park: USGS, 1991.

concerns with overdraft, groundwater quality or relative rights to make withdrawals.[55] The statutes provide considerable management flexibility including reduction or cessation of a use and allocation without regard to priority.[56] This is designed to allow management of the resource as a unit to maximize potential use and prevent irreversible harm to the State's groundwater resources. The negotiators agreed to use the general controlled groundwater statutes as a basis and to tailor them to the unique circumstances at Yellowstone National Park.

To provide a reasoned basis for the initial area boundaries and restrictions, the National Park Service contracted a group of six experts with geothermal background, referred to as "the Working Group," which was instructed by the parties that doubt on any issue should be resolved in favor of Park protection. The time frame for completion of their work was three (winter) months, which precluded the gathering of new data. A technical report detailing the group's findings was submitted to the Commission in April, 1993.[57] See Appendix K.

Recommendations by the Working Group were based on studies done for Congress by the USGS; studies on the distribution of hydrothermal and thermal features by the National Park Service; comparisons between Yellowstone National Park and developed geothermal areas in which impacts had been measured; the surface expression of a regional aquifer (the Madison Group) thought to be a conduit for recharge; and the trace of faults thought to control surface expressions of the hydrothermal system. The findings and recommendations of the Working Group were used by the negotiators to define the controlled groundwater area, identify temperature and chemical characteristics of hydrothermal water, and define restrictions for water development.

Restrictions within the area apply to new wells. The parties were unable to agree on the treatment of existing hot water wells. The U.S. maintained the right to seek an injunction against pre 1993 rights if necessary to protect the hydrothermal system within the Park.

Because the hydrothermal flow paths are poorly understood, the Compact provides for analysis of new groundwater appropriations on a case-by-case basis. It also establishes a scientific Technical Oversight Committee to review applications for the development of hot water and to review boundaries and restrictions within the area. Applications face increasing levels of scrutiny with increasing water temperature. The Compact does not restrict cold water development, but does contemplate future restrictions if the cumulative effects of development impact recharge. The

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[55]85-2-506, Montana Code Annotated.

[56]85-2-507, Montana Code Annotated.

[57]Working Group."Recommended Boundary for Controlled Groundwater Area in Montana Near Yellowstone Park." Prepared for Water Resources Division of the National Park Service for presentation to the Montana Reserved Water Rights Compact Commission. April 15,1993.

Compact also authorizes an inventory of all existing wells in the area to identify wells with anomalous temperatures.

The agreement does not represent total deference to State law, but is a State-Federal cooperative undertaking. In addition to the provisions described, the Compact (1) maintains the right of the United States, as a water right holder, to object to groundwater permits issued in the area; (2) requires reporting by the State to the NPS of all groundwater permits issued; (3) gives the United States at least two members on the scientific committee established to review area boundaries and restrictions and to review all applications for appropriation of hot water; and (4) provides Federal funding for State administration and study of the controlled groundwater area.

Funding of the Yellowstone Controlled Groundwater Area

Because the Park Service receives benefits from the Controlled Groundwater Area, and because there are national and international benefits extending beyond the boundaries of Montana, the federal government agreed to reimburse the State for the expense of establishing and administering the controlled groundwater area, and for the cost of inventory or monitoring of wells within the area, subject to appropriations by Congress. A one time appropriation of $2.3 million is necessary for this program. The Compact bill sets up a statutory appropriation to allow use of federal funding in this manner. Until this one-time appropriation is made, yearly appropriations have been made in the Yellowstone National Park budget.

Initial Boundaries of the Yellowstone Controlled Groundwater Area

As previously noted, in order to determine the boundaries of the Controlled Groundwater Area, the Park Service asked for scientific input from a Technical Working Group consisting of members from Montana State University, Bozeman; Don Michels Associates, Missoula; Montana College of Mineral Science and Technology, Butte; and the University of Montana, Missoula.

The initial boundaries of the controlled groundwater area, and Subareas 1 and 2, are illustrated on the map in Appendix F.

Establishment of the Yellowstone Controlled Groundwater Area

Within 120 days of the date funding is received to implement the Controlled Groundwater area, and within 60 days of any decision by the Department of Natural Resources and Conservation (DNRC) to modify the area, DNRC will publish notice outlining the description of all lands included in the Controlled Groundwater Area, the purpose of the area or its modification, and the permit requirements, restrictions, inventory and monitoring applicable within the discharge areas (Subarea 1), and recharge areas (Subarea 2).

Inventory and Sampling of Groundwater

Within three years of the notice, all groundwater appropriations with a priority date before the receipt of funding will be inventoried by the Montana Bureau of Mines and Geology. The inventory will include well depth, water or pump level, water temperature and, in select cases, water chemistry. The Bureau will report the results of the inventory to the State and the United States. The Bureau had made substantial progress on the Inventory as of the end of the 1996 field season.

Following the inventory, the Bureau will continue sampling wells selected in consultation with a Technical Oversight Committee. The Bureau will maintain a database on the Yellowstone Controlled Groundwater Area, which will include information from the Park Service regarding wells in the Montana portion of Yellowstone National Park. The information will be available to the public. Technical Oversite Committee members include one member appointed by the National Park Service, one appointed from the Montana University system by the Montana State Geologist, one from the U.S. Geological Survey (USGS), one from DNRC, and one selected by the other four members. Each member serves a five-year term, subject to renewal.

Modification of the Yellowstone Controlled Groundwater Area

The parties recognized that because very little is known about the extent of the hydrothermal system and the impact of development of groundwater on that system, management set up by the Compact must include the flexibility to modify the area and restrictions in light of new scientific information.

In addition to reviewing the boundaries of the Controlled Groundwater Area and initial restrictions on groundwater development and future modifications of those restrictions, the five-member Technical Oversight Committee will assess the cumulative impact of all development in the area, review changes in the groundwater and hydrothermal systems revealed by inventory and analyses done by the Bureau of Mines and Geology, review new scientific evidence pertinent to the area, present evidence and make recommendations to DNRC, and review applications for appropriation of hydrothermal groundwater on request by DNRC.

The initial review will take place within one year of the receipt of the inventory report done by the Bureau of Mines and Geology. The inventory will include all existing wells within the area.

Subsequent reviews will take place every five years or following the issuance of 75 provisional permits to appropriate water within the area by DNRC, whichever comes first. Review may also be initiated on request by the State or the United States.

Within six months of the initiation of a review, the Committee will provide a report, including recommendations for modification, to DNRC and to the Park Service. Recommendations will be based on a determination by the Committee that modification is necessary to prevent adverse effect to the hydrothermal system within Yellowstone National Park. Prior to implementation of

any recommendations, DNRC will hold a hearing in which the State, the United States, and any potentially affected party may present evidence rebutting the recommendations of the Committee.

Initial Restrictions on Groundwater Development within the Yellowstone Controlled Groundwater Area

Until the initial boundaries or restrictions are modified, the following initial restrictions apply to groundwater appropriations with a priority date on or after January 1, 1993. The restrictions will not apply to appropriations prior to January 1, 1993. However, the pre-1993 appropriations will be subject to inventory and sampling of current use in order to assess current levels of groundwater development, to record the cumulative effect of current and future development, and to provide baseline data on the characteristics of the groundwater and hydrothermal systems.

The Commission and the Park Service agreed that restrictions on use of groundwater with a temperature of less than 60°F are not currently necessary to prevent adverse effect on the Yellowstone hydrothermal system. In the future, restrictions on the development of cold water may be imposed if cold water development might injure the hydrothermal system within the Park. Cold water is considered important as recharge to the hydrothermal system. However, most areas considered to contain potential recharge are protected by Wilderness designation.

Initial restrictions on appropriations of groundwater with a temperature of 60°F or greater are designed to assure that unless the Technical Oversight Committee determines that a specific appropriation can be made without adverse effect on the hydrothermal system within the Park, no permits will be issued to develop hydrothermal water that is connected to the hydrothermal system within the Park.

An applicant to appropriate groundwater with potential connection to the hydrothermal system will have the opportunity to show by a high standard of proof that the elevated temperature is not due to discharge from the Park.

<u>**ARTICLE V: GENERAL PROVISIONS**</u>

The General Provisions article in the Compact states among other things that nothing in the Compact "may be construed or interpreted in any manner" to impact the water rights of any Indian Tribes in Montana or to impact the rights of any other federal agencies in the state.

Additional disclaimers note that the Compact may not be used as precedent for litigation or for interpretation or administration of future compacts between the United States and the State, or the United States and any other states; as a waiver by the United States of its rights under State law to raise objections in State court or of its right to seek relief from a conflicting water use not protected under the Compact; and others.

It is noted that non-use of the federal water right does not mean abandonment of the right. The United States may continue to seek water rights under State law for use outside the boundaries of federal reservations for which there are water rights settled in the Compact.

ARTICLE VI: FINALITY OF COMPACT AND DISMISSAL OF PENDING CASES

The 1993 Compact went into effect on January 31, 1994, and the 1995 Compact went into effect May 30, 1995, after they were respectively ratified by the Montana Legislature and approved by the U.S. Department of Interior and the U.S. Department of Justice. When the State Water Court issues a decree confirming the water rights in the Compact, and (upon the request of the parties) the court will dismiss the water rights claims in the Appendix to the Compact. (The Appendix is filed with the State Water Court.)

The water rights described in the Compact are full and final settlement of the federal reserved water rights claims administered by the National Park Service in Montana on the effective date of the Compact. Specifically exempted from the agreement to seek dismissal of claims are the following claims which the United States will continue to pursue as state based rights in the adjudication:

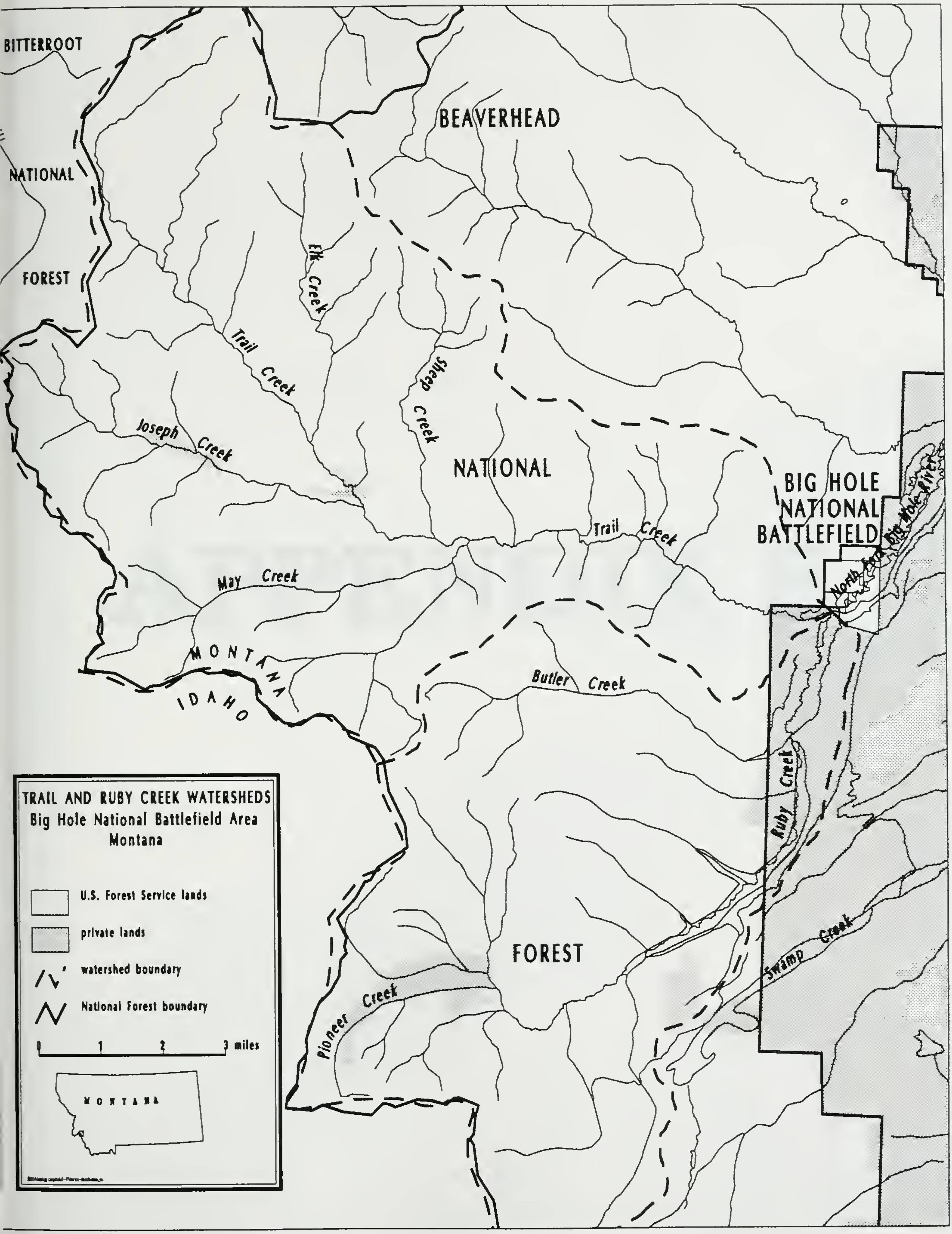
-W43P-W-162354-00 for .75cfs from Bighorn Canal for irrigation
-W43P-W162348-00 for 50 gpm from Pete's Spring for recreation and wildlife adjacent to Bighorn Canyon National Recreation Area

END

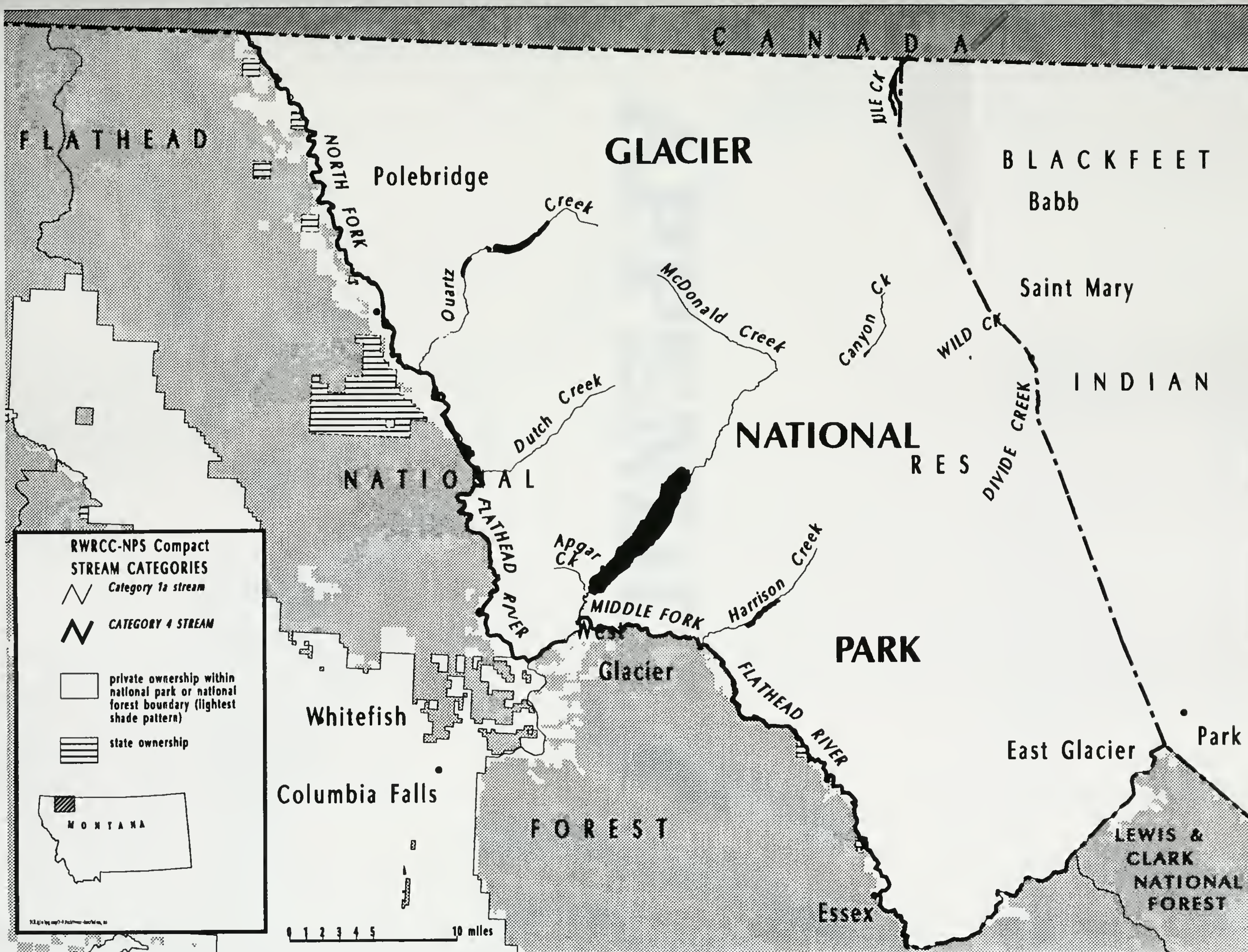
APPENDICES:

APPENDIX A -	Map of Big Hole National Battlefield
APPENDIX B -	Map of Glacier National Park
APPENDIX C -	Map of Bighorn Canyon National Recreation Area
APPENDIX D -	Map of Little Bighorn Battlefield National Monument
APPENDIX E -	Map of Yellowstone National Park
APPENDIX F -	Map of Yellowstone Controlled Groundwater Area
APPENDIX G-	Flow estimates for all streams in Compact
APPENDIX H-	Technical description of procedure for determining minimum flow, Little Bighorn River
APPENDIX I-	Working Group Report
APPENDIX J-	Definitions - Hydrologic Terms
APPENDIX K	Resumes of the technical staff who worked on the National Park Service Compact

APPENDIX A

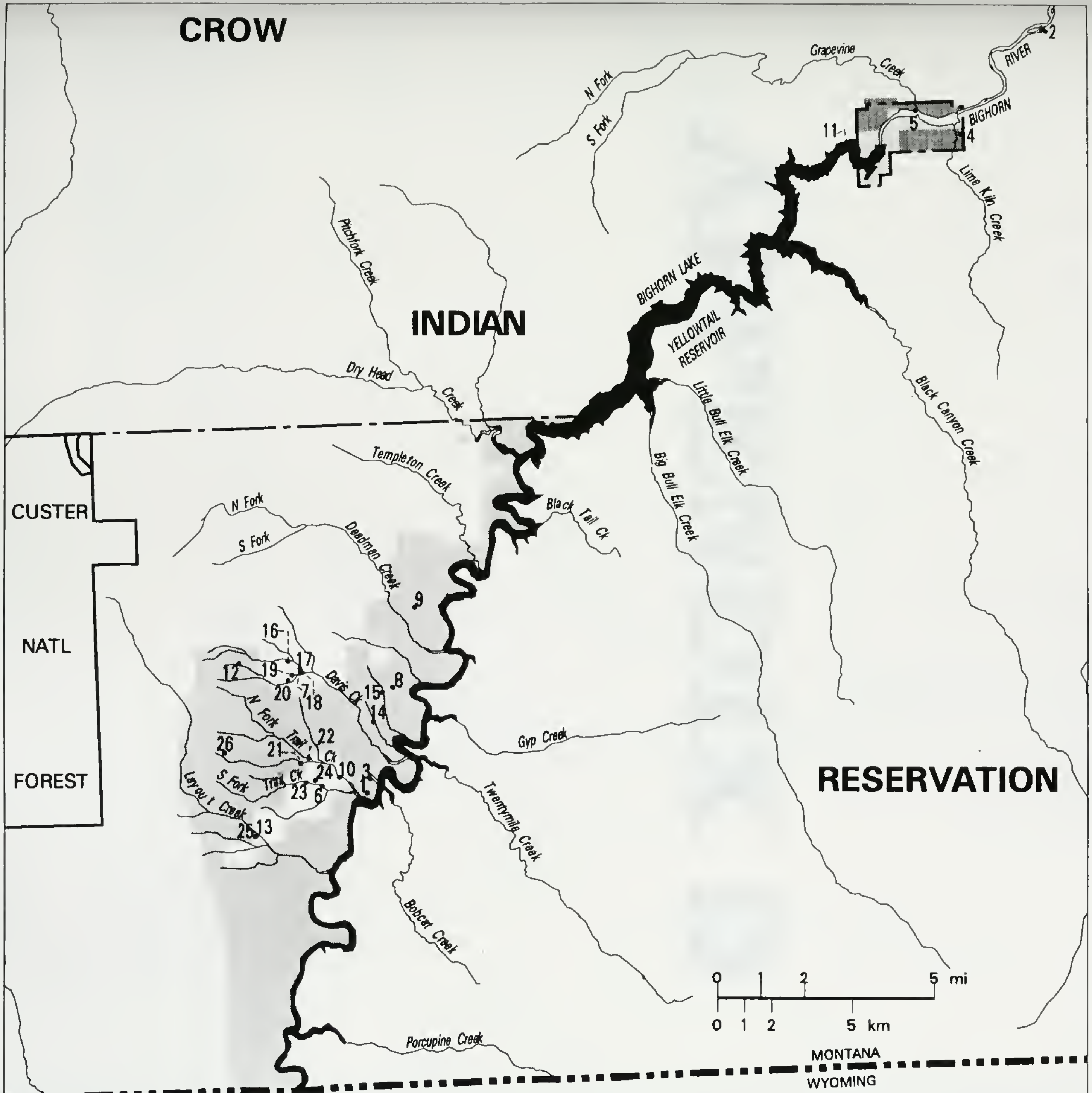

BITTERROOT
NATIONAL
FOREST
BEAVERHEAD
NATIONAL
FOREST
BIG HOLE NATIONAL BATTLEFIELD
Elk Creek
Trail Creek
Sheep Creek
Joseph Creek
Trail Creek
May Creek
MONTANA
IDAHO
Butler Creek
North Fork Big Hole River
Ruby Creek
Swamp Creek
Pioneer Creek
TRAIL AND RUBY CREEK WATERSHEDS
Big Hole National Battlefield Area
Montana
U.S. Forest Service lands
private lands
watershed boundary
National Forest boundary
0 1 2 3 miles
MONTANA

APPENDIX B



CANADA
FLATHEAD
NORTH FORK
Polebridge
GLACIER
BLACKFEET
Babb
Saint Mary
INDIAN
RES
Quartz
Creek
McDonald Creek
Canyon Ck
WILD CK
DIVIDE CREEK
Dutch Creek
NATIONAL
NATIONAL
FLATHEAD RIVER
Apgar Ck
MIDDLE FORK
Harrison Creek
PARK
West Glacier
FLATHEAD RIVER
Whitefish
Columbia Falls
FOREST
East Glacier
Park
Essex
LEWIS & CLARK NATIONAL FOREST
RWRCC-NPS Compact
STREAM CATEGORIES
Category 1a stream
CATEGORY 4 STREAM
private ownership within national park or national forest boundary (lightest shade pattern)
state ownership
MONTANA
0 1 2 3 4 5 10 miles

APPENDIX C



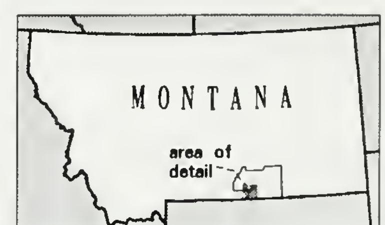
NPS RESERVED WATER RIGHT CLAIM SITES, BIGHORN CANYON NATIONAL RECREATION AREA, Montana

Bighorn Canyon Recreation Area (NPS); reserved water rights claimed

US. Bureau of Reclamation; acquired from Crow Indians by Act of Congress, 07/15/58

Crow Indian Reservation boundary

	SITE NAME	CLAIM TYPE
1	BARRYS LANDING	consumptive
2	BIGHORN RIVER RANCH	consumptive
3	CHAIN CANYON	consumptive
4	FT. SMITH VISITORS CENTER	consumptive
5	GRAPEVINE CREEK OVERFLOW	consumptive
6	HILLSBORO	consumptive
7	LOCKHART RANCH	consumptive
8	MIDDLE PASTURE CATCHMENT	consumptive
9	NORTH PASTURE CATCHMENT	consumptive
10	NORTH TRAIL CREEK	consumptive
11	OK A BEH MARINA	consumptive
12	PASTURE A CATCHMENT	consumptive
13	SORENSON RANCH	consumptive
14	MIDDLE PASTURE 1	spring
15	MIDDLE PASTURE 2	spring
16	COTTONWOOD	spring
17	LOCKHART RANCH NORTH	spring
18	LOCKHART RANCH HOUSE	spring
19	LOCKHART RANCH WEST	spring
20	LOCKHART RANCH SOUTHWEST	spring
21	NORTH FORK TRAIL CREEK	spring
22	NORTH FORK TRAIL CREEK NORTH	spring
23	SOUTH FORK TRAIL CREEK SOUTH	spring
24	SOUTH FORK TRAIL CREEK NORTH	spring
25	SORENSON RANCH	spring
26	ARC SITE	spring



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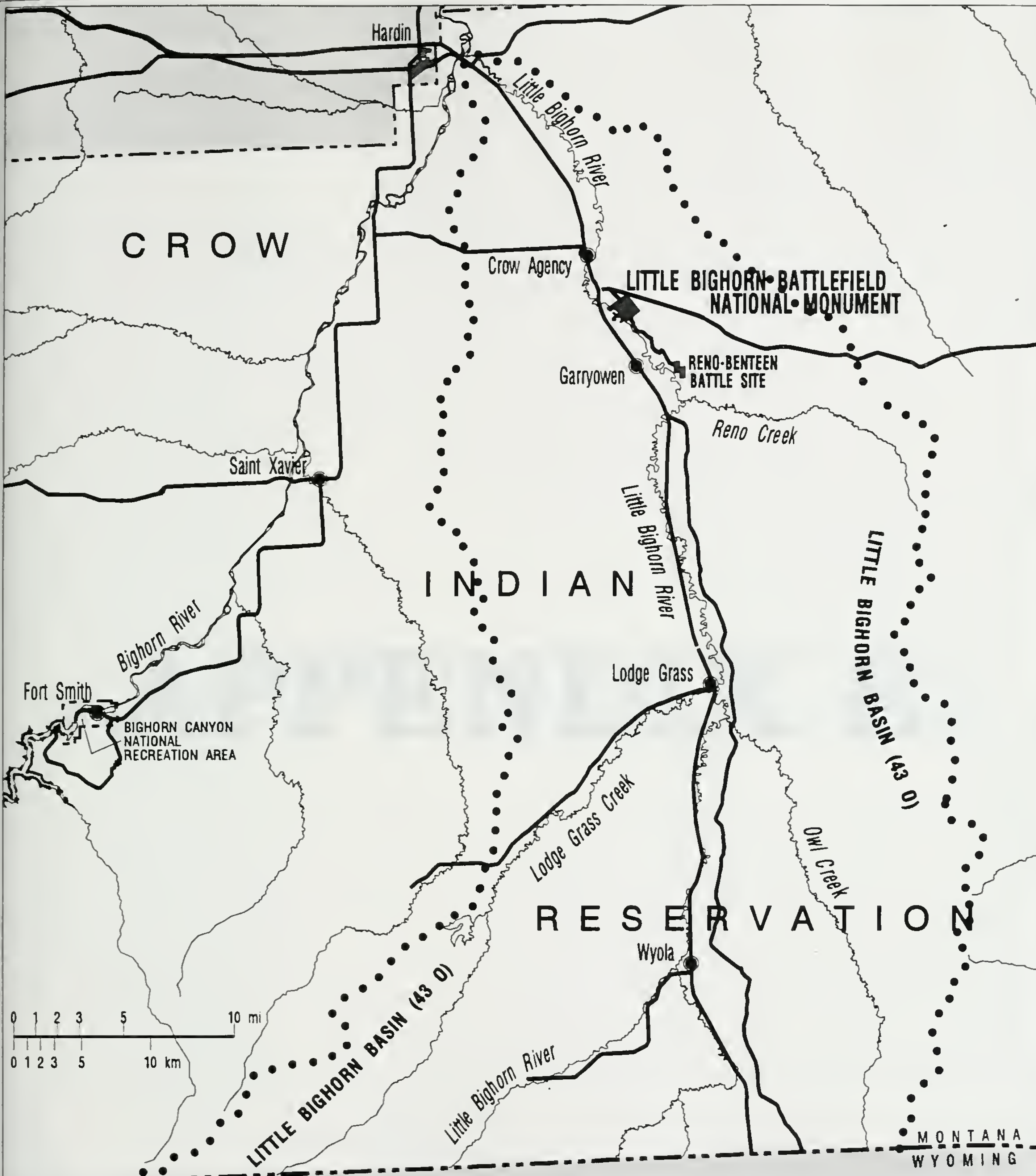
APPENDIX D



LITTLE BIGHORN BATTLEFIELD NATIONAL MONUMENT / LITTLE BIGHORN BASIN (430)

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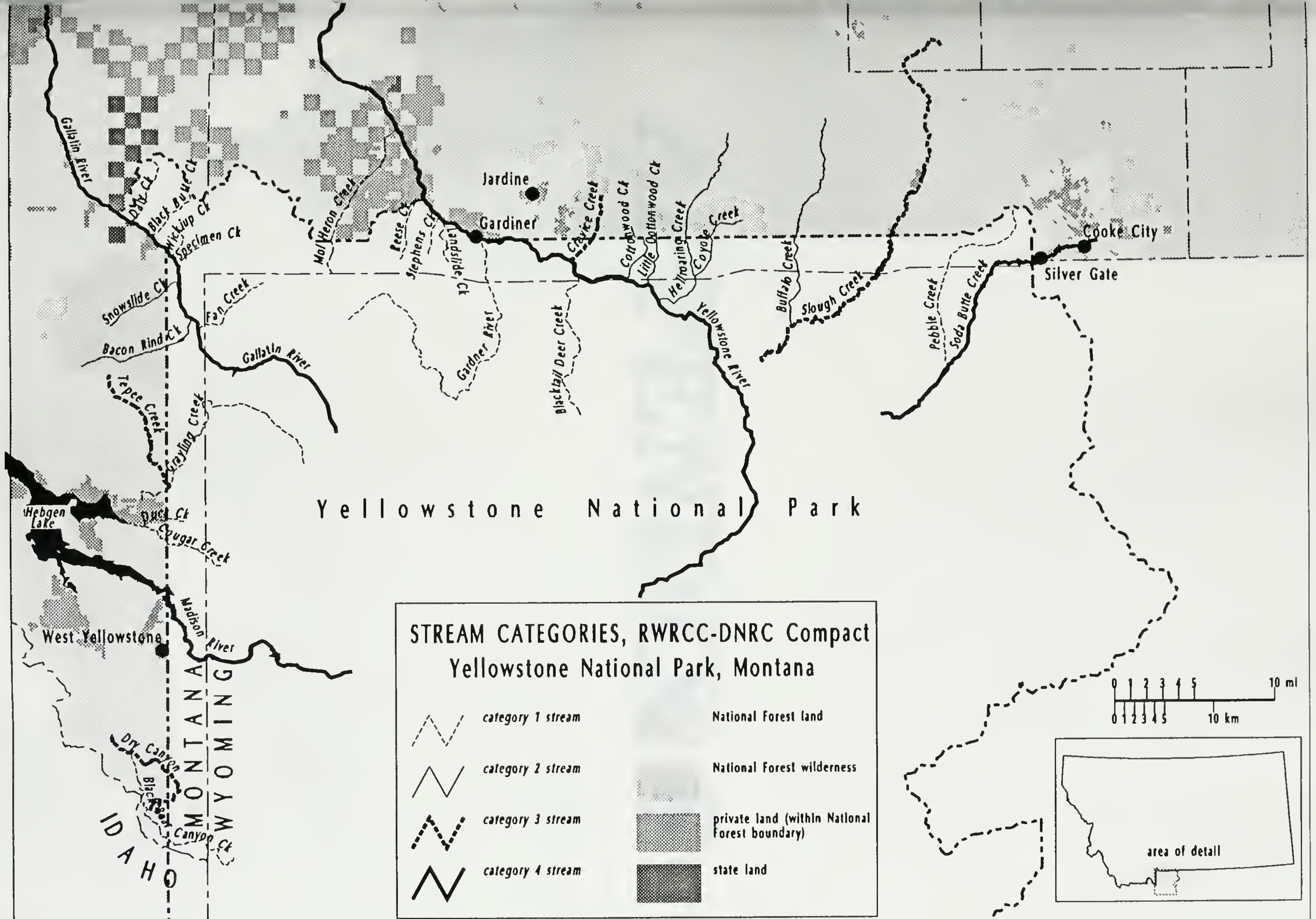
APPENDIX E



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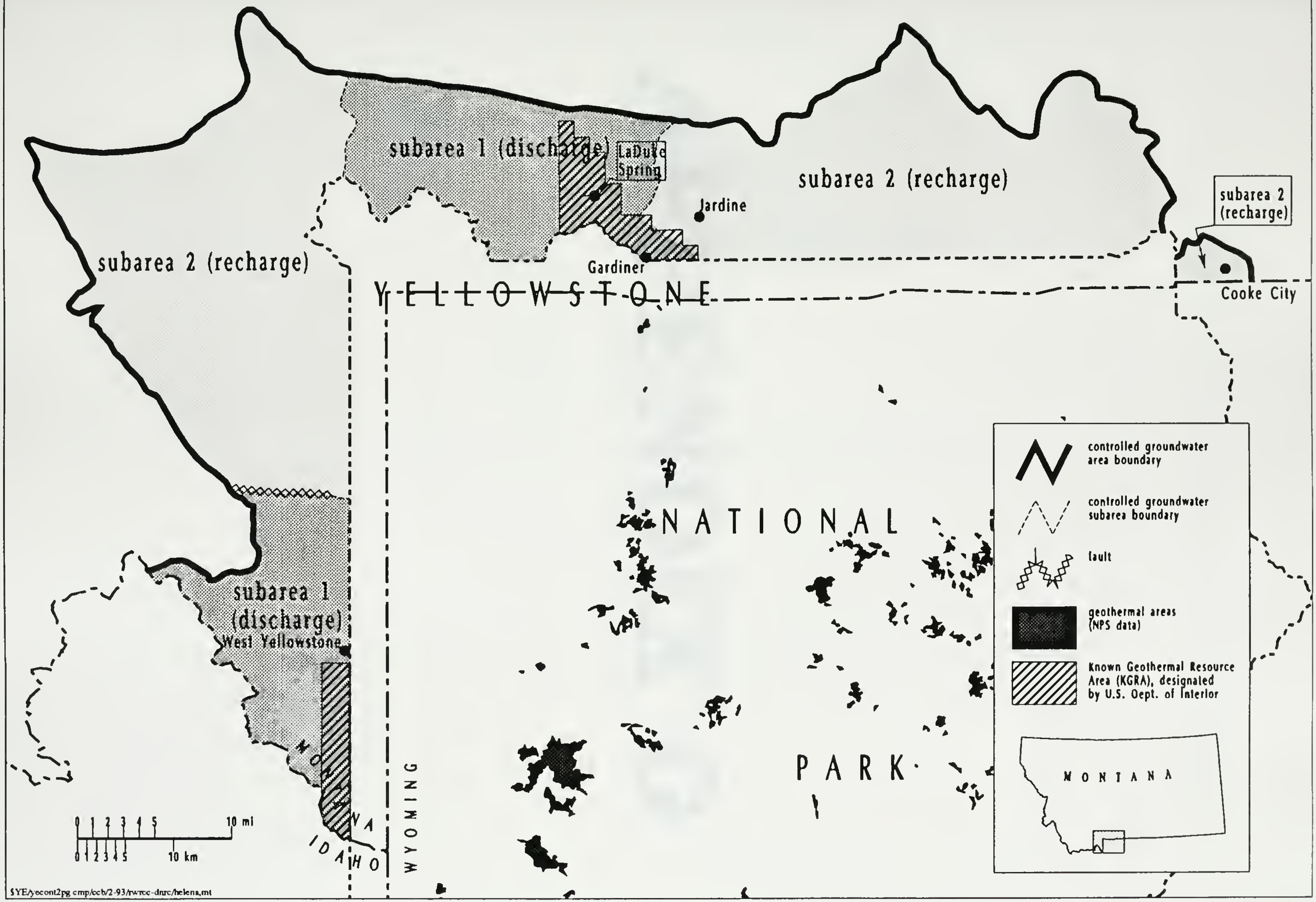
APPENDIX F

PROPOSED CONTROLLED GROUNDWATER AREAS, Yellowstone National Park area, Montana



APPENDIX G

APPENDIX G- Flow Estimates for Streams in Compact for Big Hole Battlefield, Glacier National Park, Yellowstone National Park, Little Bighorn Battlefield National Monument, Bighorn Canyon National Recreation Area

Big Hole National Battlefield Streamflow Estimates
Mean Monthly Discharge in Cubic Feet Per Second - Basin Characteristics Method

Month	Trail Creek	Ruby Creek	North Fork Big Hole River
Jan	14	5	19
Feb	14	5	19
Mar	15	6	21
Apr	73	24	97
May	380	97	477
Jun	280	94	374
Jul	58	23	81
Aug	26	9	35
Sept	20	7	27
Oct	22	8	30
Nov	19	7	26
Dec	16	6	22

Little Bighorn Battlefield National Monument
Mean Monthly Discharge in Cubic Feet Per Second - Linear Regression Method

Month	Little Bighorn River near Crow Agency
Jan	146
Feb	191
Mar	325
Apr	354
May	592
Jun	845
Jul	294
Aug	130
Sept	132
Oct	162
Nov	161
Dec	139

Glacier National Park Stream Flow Estimates
Mean Monthly Discharge in Cubic Feet Per Second - Based on USGS Gaging Station

Month	North Fork Flathead River	Middle Fork Flathead River
Jan	750	713
Feb	722	695
Mar	886	814
Apr	3,387	3,178
May	10,029	9,766
Jun	10,011	10,301
Jul	4,053	4,020
Aug	1,618	1,365
Sept	1,183	973
Oct	1,184	1,073
Nov	1,201	1,169
Dec	900	923

Soda Butte Creek at Northeast Entrance to Yellowstone National Park
Mean Monthly Flow in Cubic Feet Per Second - Concurrent Method

Month	Soda Butte Creek, NE Entrance to Yellowstone Park
Jan	5.7
Feb	5.4
Mar	4.2
Apr	1.8
May	123
Jun	350
Jul	127
Aug	48.8
Sept	16.1
Oct	14.9
Nov	9.8
Dec	6.6

Slough Creek at Entry to Yellowstone National Park
Mean Monthly Flow - Basin Characteristics/Active Channel Width Method

Month	Slough Creek at Entry to Yellowstone Park
Jan	30.4
Feb	32.2
Mar	37.3
Apr	112
May	396
Jun	448
Jul	146
Aug	58.1
Sept	46.5
Oct	48.4
Nov	41.6
Dec	35.9

Yellowstone River at Exit of Yellowstone National Park
Mean Monthly Flow in Cubic Feet Per Second. Adjusted from USGS Corwin Springs Gage Number 06191500, Water Year 1889-1894, 1910-1992.

Month	Yellowstone River at Exit of Park
Jan	826
Feb	814
Mar	890
Apr	1452
May	5674
Jun	11127
Jul	6725
Aug	3155
Sept	1938
Oct	1497
Nov	1170
Dec	947

Gallatin River at Yellowstone Park Exit
Mean Monthly Flow in Cubic Feet Per Second - Basin Characteristics Method

Month	Gallatin River at Yellowstone Park Exit
Jan	61.8
Feb	61.8
Mar	69.4
Apr	196.8
May	786.0
Jun	959.6
Jul	314.6
Aug	115.1
Sept	87.7
Oct	91.9
Nov	83.4
Dec	76.6

Tepee Creek at Entry to Yellowstone National Park
Mean Monthly Flow in Cubic Feet Per Second - Basin Characteristics/Active Channel Width Method

Month	Tepee Creek at Entry to Yellowstone Park
Jan	6.9
Feb	6.9
Mar	8.1
Apr	24.9
May	89.1
Jun	105.3
Jul	35.0
Aug	15.7
Sept	11.4
Oct	11.4
Nov	9.6
Dec	8.5

Dry Canyon Creek at Entry to Yellowstone National Park
Mean Monthly Flow in Cubic Feet Per Second - Basin Characteristics Method

Month	Dry Canyon Creek at Entry toYellowstone Park
Jan	1.1
Feb	1.1
Mar	1.2
Apr	5.0
May	25.3
Jun	24.1
Jul	7.0
Aug	3.3
Sept	2.1
Oct	2.0
Nov	1.6
Dec	1.5

Crevice Creek at Entry to Yellowstone National Park
Mean Monthly Flow in Cubic Feet Per Second - Basin Characteristics/Active Channel Width Method

Month	Crevice Creek at Entry to Yellowstone Park
Jan	4.0
Feb	4.8
Mar	5.5
Apr	21.3
May	75.6
Jun	67.2
Jul	19.7
Aug	8.5
Sept	7.4
Oct	7.5
Nov	5.4
Dec	4.1

Bear Creek at Entry to Yellowstone River (not in Park)
Mean Monthly Flows in Cubic Feet Per Second - Basin Characteristics Method

Month	Bear Creek at Entry to Yellowstone River
Jan	11.7
Feb	11.9
Mar	14.1
Apr	42.4
May	160.0
Jun	178.0
Jul	58.1
Aug	25.0
Sept	18.9
Oct	19.0
Nov	16.2
Dec	14.2

Eagle Creek at Entry to Yellowstone National Park
Mean Monthly Flow in Cubic Feet Per Second - Basin Characteristics Method

Month	Eagle Creek at Entry to Yellowstone Park
Jan	0.7
Feb	0.8
Mar	1
Apr	3.3
May	11.8
Jun	11.2
Jul	3.6
Aug	2
Sept	1.5
Oct	1.4
Nov	1
Dec	0.9

Phelps Creek at Entry to Yellowstone National Park
Mean Monthly Flow in Cubic Feet Per Second - Basin Characteristics Method

Month	Phelps Creek at Entry toYellowstone Park
Jan	0.5
Feb	0.5
Mar	0.7
Apr	2.3
May	8.5
Jun	7.9
Jul	2.5
Aug	1.4
Sept	1
Oct	0.9
Nov	0.7
Dec	0.6

Lodgepole Creek at Entry to Yellowstone National Park
Mean Monthly Flow in Cubic Feet Per Second - Basin Characteristics Method

Month	Lodgepole Creek at Entry to Yellowstone Park
Jan	0.7
Feb	0.7
Mar	0.8
Apr	3.1
May	15.3
Jun	14.2
Jul	4.2
Aug	2.1
Sept	1.4
Oct	1.3
Nov	1
Dec	0.9

Monument Creek at Entry to Yellowstone National Park
Mean Monthly Flows in Cubic Feet Per Second - Basin Characteristics Method

Month	Monument Creek at Entry to Yellowstone Park
Jan	1.5
Feb	1.4
Mar	1.7
Apr	4.7
May	17.5
Jun	24.3
Jul	8.4
Aug	4.3
Sept	2.7
Oct	2.5
Nov	2.2
Dec	2.1

Madison River
Mean Monthly Flows in Cubic Feet Per Second - From USGS Gage Number: 06037500
Water Years 1913-1973, 1983-1986, 1989-1991

Month	Madison River
Jan	397
Feb	393
Mar	399
Apr	486
May	818
Jun	803
Jul	493
Aug	428
Sept	422
Oct	428
Nov	419
Dec	408

APPENDIX H

Date: August 9, 1994

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Rights Compact Commission

Subject: National Park Service (NPS) and Montana Reserved Water Rights Compact Commission (RWRCC) hydraulic calculations, using Manning's Equation, for Little Bighorn River at Little Bighorn Battlefield National Monument (LBBNM).

Purpose: The purpose of this exercise was to 1) determine the Manning's "n" value associated with an appropriate channel cross section at one high and one low flow, and 2) use the field determined n-values to estimate the channel maintenance discharge at bankfull stage, and to estimate discharge for a low flow stage that also serves a channel maintenance purpose as well as LBBNM scenic interpretation purposes.

High Flow Data Workup, Cross Section Number 1

High flow data were collected on June 1, 1994, at Cross Section Number 1. This cross section is located within a lower reach of the river as it borders LBBNM (see FIGURE 1). The observed flow of 543 cfs was 1.40 feet below the average bankfull elevation at the cross section--ie, the average of right and left bank bankfull elevations (see FIGURES 2 and 3).

Flow was measured using RWRCC field equipment. Cross section survey data was collected using NPS's SET4 Total Station. Survey data were used to do area and perimeter calculations, and to determine water slope.

Manning's Equation gives mean velocity. In turn, the product of mean velocity and area equals discharge. Restating this: Discharge = (Result from Manning's Equation) x (Area)

For the following data, we have measured values for all parameters except Mannings' n, and can therefore solve for n: Discharge = Q = 543 cfs

Area = A = 241 sq-ft
Wetted Perimeter = P = 79.8 ft
Hydraulic Radius = R = A/P = 241/79.8 = 3.02 ft
Water Slope = s = .0007 (from station downstream to station upstream of the cross section)
Manning's n = n

$$Q = (1.486/n)(R^{2/3})(s^{1/2})(A)$$

$$543 = (1/n)(1.486)(2.09)(0.0258)(241)$$

$$543 = (1/n)(19.34)$$

$$n = 19.34/543$$

= 0.036

This n-value allows an estimation of discharge for the case where water stage at Cross Section 1 increases to the bankfull elevation:

Discharge = Bankfull Q
Area = A = 347 sq-ft
Wetted Perimeter = P = 84.0 ft
Hydraulic Radius = R = 4.13 ft
Water Slope = s = .0007 (held the same as for observed flow)
Manning's n = 0.036 (" ")
Bankfull Q = (1.486/0.036)(2.57)(0.0258)(347)

= 950 cfs

Examination of USGS gaging records just downstream of the battlefield (discontinued station number 06293500, period of record 1912-1924, 1928-1933, 1938-1960), shows that the approximate return period of this event is 1.3 years. The median length of the event exceeding 950 cfs is 11 days. The maximum number of days in excess of 950 cfs in one year was 76 and occured in 1924. There were several years during which there were no flows exceeding 950 cfs.

Low Flow Data Workup, Cross Section Number 2

Low flow data were collected on July 27, 1994, at Cross Section Number 2. This cross section is a riffle feature located within a lower reach of the river as it borders LBBNM. It is just downstream of Cross Section Number 1 and a bend in the river (see FIGURE 1). The observed flow of 121 cfs was measured at 0.46 feet above a water stage necessary to keep stream bed sediments wet to minimize vegetation encroachment and to maintain mobility of bed materials, and to permit LBBNM's scenic interpretation purposes (see FIGURE 4).

Flow was measured using RWRCC field equipment. Cross section survey data were collected using NPS's SET4 Total Station. Survey data were used to do area and perimeter calculations, and to determine water slope.

Using a comparable analysis as for the high flow data workup:

Discharge = Q = 121 cfs
Area = A = 87.4 sq-ft
Wetted Perimeter = P = 84.3 ft
Hydraulic Radius = R = 87.4/84.3 = 1.04 ft
Water Slope = s = .0015 (based on water slope data for a
similar riffle, channel at left side
of island, just upstream of bend)
Manning's n = n

$Q = (1.486/n)(R^{2/3})(s^{1/2})(A)$

$121 = (1/n)(1.486)(1.03)(0.0387)(87.4)$

$121 = (1/n)(5.177)$

$n = 5.177/121$

$= 0.043$

This n-value will allow an estimation of discharge for the case where water stage at Cross Section 2 decreases to the low flow elevation:

Discharge = Low flow Q
Area = A = 50.8 sq-ft
Wetted Perimeter = P = 78.0 ft
Hydraulic Radius = R = A/P = 0.651 ft
Water Slope = s = .0015 (held the same as for observed flow)
Manning's n = 0.043 (" ")

Low Flow Q = (1.486/0.043)(0.751)(0.0387)(50.8)
= 51.0 cfs

The USGS gaging records show that the median number of days per year during which flows dropped below 51 cfs was 2. During the period of record, 19 years had no flows below 51 cfs and 28 years had 8 or fewer days during which flows dropped below 51 cfs. The number of days not reaching 51 cfs in a year ranged from 77, in 1951, to zero in several years.

APPENDIX I

RECOMMENDED BOUNDARY

for

CONTROLLED GROUNDWATER AREA IN MONTANA NEAR YELLOWSTONE PARK

Prepared for

Water Resources Division

NATIONAL PARK SERVICE

U.S. DEPARTMENT OF INTERIOR

for presentation to:

MONTANA
RESERVED WATER RIGHTS COMPACT COMMISSION

by

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I. INTRODUCTION

The hydrothermal resources of Yellowstone National Park are an important national treasure which should be protected. Such protection was one of the reasons for establishment of the Park and this commitment continues today (U.S. Congress, 1992). Development of hydrothermal resources similar to those found in and near the Park has impacted surface hydrothermal features and hydrothermal systems in other regions of the world (eg: Allis and Lumb, 1992; Bradford, 1992; Cody and Lumb, 1992; Bjornsson and Steingrimsson, 1992; U.S. Congress, 1992; Kerr, 1991; Narasimhan and Goyal, 1984, Allis and Barker, 1982; Allis, 1981; Donaldson, 1979; Hatton, 1970; Boulton, 1970; Studt, 1958). These impacts have occurred in response to development for domestic and hotel use (Allis and Lumb, 1992; Bradford, 1992) as well as at power generation facilities (Narasimhan and Goyal, 1984; Allis and Barker, 1982). Aware of the potential for hydrothermal development adjacent to the Park, the Montana Reserved Water Right Compact Commission and the National Park Service are discussing the implementation of a Controlled Groundwater Area to protect the hydrothermal resource from impact by groundwater development outside the Park. The Controlled Groundwater Area would be promulgated under Montana law, and would apply only to those areas adjacent to Yellowstone National Park in Montana.

A technical working group was organized to assist with definition of the boundaries of a Controlled Groundwater Area. The working group was constrained to <u>literature-based analysis</u> because of the short time-frame (3 months) between task identification and the deadline for recommendations. The short time frame was necessary to provide input to the 1993 Reserved Water Right Compact negotiations prior to Montana Legislative session.

Review of the literature demonstrates that there are limited physical data with which to describe and quantify the hydrothermal flow system in the Park. Even in well-known systems the high cost of monitoring wells, which may need to be thousands of feet deep, limit the availability hydrogeologic information at the resource-area margins. Data needed include water temperature, total head at both shallow and deep levels in both the recharge and discharge areas, measured transmissivity and storativity, as well as geologic data on subsurface stratigraphy, primary hydrogeologic units, structure, fracture location, fracture width, anisotropy and heterogeneity. Although some data exist, much of the critical data do not exist and cannot be reasonably expected in the near future. Similarly, in New Zealand, "...(there is a) large amount of data available for a relatively shallow, horizontal slice of part of the field, but very poor information on the depth dimension of the field. ... This limits the accuracy of even conceptual hydrological models of the field which usually indicate the location of an "up-flow zone" at several kilometers depth, and the location of boiling and dilution processes in "outflow zones" typically within a kilometer of the surface" (Allis and Lumb, 1992, p. 14). The working group

considered the application of numerical models to assess impacts. This approach was rejected for the present analysis because of data limitations.

A literature review was conducted for developed geothermal fields in the world where **both** an impact **and** a diameter of effect was reported (Table 1). This data provided perspective regarding known impact distances in other systems and was used to assist with discharge area impacts discussed later. The data reported were limited to developments in hydrothermal-flow systems similar to that in and around Yellowstone National Park (magmatic heat source in a caldera complex where the system is dominantly a high-temperature hydrothermal system as opposed, for example, to a vapor-dominated system) (Fournier and others 1976; Fournier and Pitt, 1985). Although perspective can be gained by analogy, precise correspondence between systems is unlikely because of hydrostratigraphic complications introduced by the cratonic sedimentary-rock terrain in which the caldera complex formed. Measured impacts from geothermal development, such as land subsidence have been reported over diameters ranging from one to seven miles, pressure drops over distances from 0.5 to 10 miles and changes in heat flow and geyser activity over a distance of about one mile (Table 1). The table does not identify all impacts. Some impacts have no clear distances associated with them and were not recorded. Furthermore, some impacts may exist which remain unmeasured or are unrecognized. The working group did not speculate on such unmeasured or unrecognized impact distances.

Four points should be kept in mind when reviewing Table 1. First, subsidence is a good first estimate of impact distance. However, the pressure effects from development will likely extend farther from the development center than the measured subsidence distance. Second, to conclude that any development no matter how small would produce effects at the largest distance would be incorrect. The effects reported in Table 1 resulted from high rates of water removal (5000 to more than 70,000 gpm) continuously over several years with little reinjection. Some of the effects might have been smaller if the appropriate modern practice of reinjection had been utilized. None-the-less, data in Table 1 do provide perspective regarding the distance of impact that could occur should large-scale development be contemplated. Third, Table 1 reports diameters not radii. Use of measured diameters of influence introduces a factor of safety of two because one would expect geothermal development to be centered in the zone of influence with the radius rather than the diameter representing the impact distance from the development center. (Diameters are twice the radius.) Furthermore, the largest diameter was measured if impact distribution in the area of known development was irregular or elliptical. Thus the diameters reported are inherently conservative. Fourth, the diameter of influence generally includes all wells in the development system. Thus, the distance to the edge of the measured impact may not be very far from the outermost extraction well. One should not conclude from data in Table 1 that a single well is responsible for the measured impact.

Table 1. Maximum reported diameter of impact from developed geothermal areas described in the literature. Data are organized by impact type. Within type, data are ordered based on location. Within location, data are organized by date.

Impact	Distance	Location	Source
Subsidence	3.8 mi	Broadlands, NZ	Narasimhan and Goyal, 1984
Subsidence horizontal component	4.7 mi	Broadlands, NZ	Narasimhan and Goyal, 1984
Subsidence/uplift	22 mi	Cerro Prieto*	Narasimhan and Goyal, 1984
Subsidence	7 mi	Iceland	Bjornsson and Steingrimsson, 1992
Subsidence	1.2mi	Wairakei, NZ	Hatton, 1970, Figure 1
Subsidence	2 mi	Wairakei, NZ	Hatton, 1970, Figure 2
Subsidence	4 mi	Wairakei, NZ	Allis and Barker, 1982
Subsidence horizontal component	2 mi	Wairakei, NZ	Narasimhan and Goyal, 1984
Subsidence	1.4 mi	Wairakei, NZ	Narasimhan and Goyal, 1984
Pressure drop	10 mi	Tauhara, NZ	Allis, 1982
Pressure drop	1.7 mi	Wairakei, NZ	Allis and Barker, 1982
Pressure drop	0.5 mi	Wairakei, NZ	Studt, 1958
Heatflow change	1 mi	Wairakei, NZ	Allis, 1979

*Cerro Prieto data may be influenced by tectonics.

The literature review was supplemented by a hydrogeologically based conceptual model which used the geologic framework and hydrologic principles to assess where impacts might be expected. This approach was based on topographic analysis (Toth, 1962). The approach does not account for the influence of changing head on the groundwater divide. Furthermore, the topographic approach has limitations in stratigraphically controlled hydrothermal-flow systems where recharge may occur at locations other than topographic divides and where thermal buoyancy causes water to rise. However, topographic analysis does provide a first order estimate of the location of recharge areas, and stratigraphic control of recharge can be accounted for at least conceptually.

The definition of a geothermal resource is of interest because this resource is to be protected. A variety of perspectives were examined ranging from the heat resource, developable heat resource, hot groundwater, the surface expression of hot groundwater (eg: hydrothermal alteration, hot ground, hot pools, hot springs, mud pots, and geysers), and the tourist resource which is attracted by the surface expression of the geothermal resource. The consensus reached was that the hydrothermal-flow systems in Yellowstone National Park, parts of which extend outside the Park, constitute the geothermal resource. This approach was adopted because these flow systems form the underpinnings of all hydrothermal features and processes both surface and subsurface. Hydrothermal-resource protection requires that all parts of the flow system (recharge, transmission, and discharge) be carefully monitored, evaluated, and regulated if the resource inside the Park is to be protected.

The controlled groundwater area boundary was drawn with some operational goals in mind. Inside the area, groundwater withdrawal or injection should be regulated where such groundwater use effects a hydrothermal system in the Park. The working group did not intend to imply that all geothermal development activity should be eliminated because prohibition of all withdrawal irrespective of whether it effects the Park could be construed as an anti-development stance. Such political decisions were left to the Compact Commission. The boundaries were drawn so that inventory, monitoring and regulation could be used to assure that no impact to the Park results from use of wells in the Controlled Groundwater Area. Recommendations regarding inventory, monitoring and regulation to protect the hydrothermal-flow systems from geothermal development impacts are presented later.

The working group was encouraged by the Reserved Water Rights Compact Commission staff and Water Rights staff of the National Park Service to encompass within the Controlled Groundwater Area all regions that might reasonably be expected to influence the Yellowstone National Park hydrothermal systems so that water users with groundwater activities in this region could be notified of monitoring and evaluation activities, and the possibility of regulation. Water users outside the area could expect not to be brought under control, and could expect no increased regulation under Montana law. "If there is the least doubt that an area might be part

of the hydrothermal-flow system, part of which is in the Park, that area should be placed in the Controlled Groundwater Area. Unless you are absolutely certain there is no effect expected in this area, assume there is an effect" (Owen Williams, National Park Service).

The objective of this analysis is to delineate a Montana Controlled Groundwater Area for the long-term protection of the hydrothermal systems in Yellowstone National Park.

II. RATIONALE USED FOR ESTABLISHING BOUNDARIES OF A CONTROL ZONE

A. System Concept

The Working Group recognizes that surface hydrothermal features of Yellowstone Park are merely the uppermost portions of several thermo-hydraulic systems driven by heat sources at depth. The hydrothermal-flow system includes recharge, transmission, heating, and discharge components.

Recharge to the system begins when water enters a shallow groundwater flow system either through the alluvium, through direct shallow entry into transmissive formations or through the very-near-surface parts of fracture systems. Because of the large area in which recharge can occur, impact to this system is unlikely unless withdrawals are large, focused on fractures, or many small withdrawals sum over a relatively large area to influence the hydrothermal-flow system in the Park. Not all shallow surface recharge is connected to the deep system. However, a portion is transmitted at depth in fractures and transmissive formations. Impacts to the recharge of hydrothermal systems may occur in these deeper transmission areas if withdrawals are very large or focused on an important transmission zone connected directly to the the deep system. If data come to show that cold-water recharge is not important as recharge to the hydrothermal-flow system, then restraints on well usage could be relaxed. The working group is unaware of any documented case in which recharge interuption or reduction has impacted a geothermal system, but the continuity equation suggests that such interuption is possible. The time between recharge interuption or reduction and impact on the hydrothermal flow system may be quite large since the lengths of the flow lines in the system may be quite large.

When recharge water encounters the heat source, the water is heated, becomes less dense, and starts to rise. This density contrast contributes to the driving force which is responsible for near-vertical-upward flow associated with the central portion of the hydrothermal-flow system. As the hot water rises toward the surface, it commonly interacts with near-surface cold water. Surface features may develop with highly variable and changing expression of the dynamic interaction between cold and hot groundwater flow systems. Manifestations include fumaroles, hot or boiling

springs, geysers, hot pools, and mud pots. The feature formed depends on hydraulic heads, temperatures, chemical self-sealing by siliceous sinter or travertine, rock-water interactions, and other dynamic factors. These features typically overlie the core of the hydrothermal system. On the margins of the core, the hot water floats over more dense cold-water and overlies the cold-water recharge portion of the flow system. Warm springs are commonly found in such areas.

The shallow, cold-water surroundings which receive some thermal waters are not normally connected directly to the hydrothermal system except in the zone of mixing. Discharges from springs and shallow wells, which carry a thermal signature (possibly chemical) should be regarded as a mixture of shallow, cold groundwater and hot water from a deeper thermal system, until contrary evidence is developed. Protection of the Park hydrothermal system requires that withdrawals from the flow systems outside of the Park produce no impact inside the Park. This requires that recharge to the hydrothermal system not be substantially reduced or disrupted, and that development in areas of thermal discharge from the Park do not reduce heads or temperatures in the hydrothermal-flow systems within the Park. In principle, out-of-Park use of warm water discharged naturally from the Park could be allowed so long as the manner of capture is not projected or observed to impact the hydrothermal system in the Park.

B. BASE MAPS USED TO DRAW THE BOUNDARY

1. Topographic Base. The working group used 1:250,000 Army Map Service (AMS) topographic maps as the base. The topography (200 foot elevation contour interval) was used to estimate recharge and discharge elevations (see below). This report is accompanied by a copy of the topographic base map and a clear transparent overlay which shows the Controlled Groundwater Area Boundary. Those interested in geographic information regarding locations should refer to this overlay system of maps.

2. Surface Hydrothermal Features. A map of the surface hydrothermal features was transferred by enlargement from White and others (1988). A map of thermal features was also produced from an Arc/Info computer file by Yellowstone National Park Geographic Information staff with the caveat that the data were incomplete in the northern part of the Park. Our research to date suggests that no single complete compilation of all surface hydrothermal features exists for Yellowstone Park at this time. The compilation from White and others (1988) and data from a map of hydrothermal springs in Wyoming (including Yellowstone National Park) (Heasler and others, 1983) were also used and constitute the best published data.

The thermal features are widely known to change naturally (eg: Bargar, 1978). Thus the position and even the behavior of a single feature cannot be considered constant even under natural conditions. Changes may be induced by processes such as chemical precipitation, changes in precipitation regime, changes in the rock properties due to earthquakes and rock fracture. Furthermore, the surface expression of the hydrothermal system at Yellowstone National Park simply represents the fringes of the rising hydrothermal-flow system. The surface expression of the hydrothermal-flow system is often what comes to mind when one thinks of protection of the hydrothermal resource, but successful protection must account for the entire flow system rather than just the discharge area. The total flow system rather than the surface feature should be the focus of the control activities. For this reason, the map of surface hydrothermal features and thermal springs was used primarily to estimate reasonable recharge elevations which, as a first approximation, must lie above the discharge elevations.

3. Hydrothermal Recharge-Discharge Areas. Recharge areas for thermal water in Yellowstone Park are important to the flow system as are the discharge areas for such a system. Accurate determination of the location of such areas is extremely difficult without an inventory of hydraulic-head data, groundwater-temperature data and heat-source data. In the absence of such data, a watershed analysis was utilized. The recharge elevations are probably not higher than the discharge elevations because the potential energy of the hydrothermal-flow system is dictated in part by the elevation of the recharge area. (Potential energy is dictated by the elevation of the recharge area and drives the local and regional groundwater flow systems. Energy loss due to friction during transmission is unknown and unaccounted for, but may be balanced in part by another unknown, energy addition from buoyant forces due to heating.) A watershed map was constructed which shows the surface-water drainage divides and their relationship to the Park Boundary. Areas where surface water flows into the Park were assumed to be areas of groundwater recharge. Areas where surface water flows out of the Park were assumed to be areas of groundwater discharge. The Park Boundary is the divide between surface-water flow systems at several locations. In these areas a groundwater no-flow boundary (flow neither into nor out of the Park) was indicated.

There is some evidence that this approach is reasonable. Discharging thermal water in alluvial systems is known in the Yellowstone Valley and in the Madison Valley near West Yellowstone and Hebgen lake (Sonderegger and Bergantino, 1981). Thermal water is also thought to exit the Park in these areas based on geochemical arguments (Fournier and others, 1976; Friedman and Norton, 1990; Sorey, 1991). Recharge to the hydrothermal-flow system from an area to the north outside Yellowstone National Park is suggested by hydrogen isotope data (Rye and Truesdell, 1992). The current data suggests that sources capable of delivering water with this signature must occur at high elevations north of the Park.

There are at least two areas where recharge-discharge relationships based on the above criteria are highly uncertain. One is along the northern Park Boundary near where Bear Creek enters the Yellowstone River. Technically, Bear Creek forms a confluence with the Yellowstone River outside the Park. Just down stream, however, the Yellowstone River flows back into the Park and Eagle Creek also flows into the Park to join the Yellowstone. The Yellowstone again leaves the Park near Phelps Creek. The drainage divide separating inflow (recharge) and outflow (discharge) was taken to be at the eastern Bear Creek divide in this area. Bear Creek divide was chosen because Bear Springs discharges thermal water just outside the Park Boundary and is in this drainage basin. Although the chemical data does not directly link Bear Springs to the Yellowstone hydrothermal system, proximity to the Park suggests inclusion in the discharge area until more detailed analysis demonstrates unequivocally exclusion is warrented. A second uncertain area is at the northwestern Park boundary. Here Tepee Creek enters the Park (recharge) and immediately leaves the Park as part of Grayling Creek (discharge). The western Tepee Creek drainage divide was used to form the recharge area boundary in this area because nearly all water in Tepee Creek does enter the Park.

<u>4. Madison Group Outcrop.</u> Recharge to the hydrothermal system is probably not constrained to surface-water divides in all areas. In particular, the Mammoth Hot Spring flow system is thought to be related to flow in the Madison Aquifer (Struhsacker, 1976; Bargar, 1978; Sorey, 1991). The Madison Aquifer may also contribute water to other hot springs with travertine such as Terrace Springs near Madison Junction. The Madison Aquifer is intepreted to be equivalent to the Madison Group (Balster, 1971, p. 229). Given the fact that the Madison Group is known to be important regionally and contains both dolomite and solution porosity and permeability in the area (for example, see Clarke, 1991 for a summary), the working group assumed that outcrops of the Madison Group, particularly above 6200 feet above sea level, should be considered candidates for recharge to the hydrothermal-flow system in Yellowstone National Park. The 6200 foot elevation is based on the approximate lowest elevation of known travertine springs which discharge thermal water in the Park. An overlay of surface outcrops of Madison Aquifer rocks was compiled from a variety of sources.

The primary source for Madison Group outcrop data is an unpublished preliminary geologic map compilation for the Bozeman 1 x 2 degree AMS sheet. This preliminary compilation was prepared by Dr. Donald Smith at a scale of 1:125,000 in the early 1980's at the Department of Earth Sciences at Montana State University in Bozeman, MT. No such coverage is known to exist for the Ashton, Billings or Cody AMS sheets. Madison Group outcrop areas in Montana covered by sheets other than the Bozeman sheet were compiled from Lovering (1929), Ross and others (1955), Egbert (1960); Witkind (1969, 1972a, b; 1975, 1976); Fraser and others (1969), U.S. Geological Survey (1972 b); Prostka and others (1975); Elliot (1979); and Pierce (1987). Many of the primary maps provide little information on the attitude (dip and

strike) of the Madison Aquifer. At a few locations, dip and strike were plotted near the outcrops on the map to provide a sense of the structural geology for the units. One must recognize that much of the geologic mapping in this region has been at the reconnaissance level, and that numerous contradictions exist in the literature regarding the precise location of the Madison Aquifer. Such problems could not be resolved in the time frame required for this project. Although positions of the Madison Aquifer are in some cases uncertain, the general position of the outcrops as depicted on the working overlay of Madison Aquifer Outcrop are approximately correct.

5. Alluvium. In addition, discharge occurs through alluvium. Sources for general information about alluvium include Ross and others (1955); U.S. Geological Survey (1972a); Pierce (1973); Fournier and others (1976); Friedman and Norton (1990), and Clarke, (1991); Sorey (1991). No overlay of alluvium was made. Rather, interpretations depend on the sources listed.

6. Faults. Another significant geologic avenue for recharge and discharge is along faults. A working geologic overlay of faults was created. The position of the faults is known with varying degrees of certainty, but did guide the working group regarding possible fault control of the hydrothermal flow system in the region. The sources are the same as those indicated above. In addition, new work and syntheses by Personius (1982), Schmidt and Garahan (1983), and Sorey (1991) were incorporated on the overlay.

III. CONTROLLED GROUNDWATER AREA BOUNDARY DESCRIPTION

A. SCALE

The scale at which the Controlled Groundwater Area Boundary is drawn is important both for practical and philosophical reasons. Common map scales exist which might serve as a base map (eg: 1:1,000,000; 1:500,000; 1:250,000; 1:100,000; 1:125,000; 1:62,500; and 1:24,000). The scale chosen depends in part upon availability. Additionally, scale influences the manageability of the boundary at meetings and for presentations. More importantly, scale impacts the map-readers' perception of boundary precision. Finally, and most importantly, scale influences how the human mind perceives the system. The working group selected a scale of 1:250,000 (1 X 2 degree U.S. Army Map Service Topographic Sheets.(AMS Sheets). This scale is available as a topographic map with 200 foot contours. The scale allows presentation of Yellowstone National Park and the areas adjacent to the Park in Montana in a form that can nominally be handled as a wall or table map. This scale also represents, qualitatively, a degree of uncertainty regarding the precision of the boundary line which will be discussed subsequently.

Several other scales were rejected. The 1:24,000 scale topographic maps are not available throughout the area of interest. The 1:62,500 scale maps are currently out of print, but a few exist. This scale was explored. The assembled maps were judged too large for presentation and imply too high a degree of precision. While data from these maps were used for elevation control, this scale was rejected. 1:100,000 topographic sheets were considered. Topographic maps at this scale exist for all of Wyoming, but this scale was rejected because critical sheets in Montana along the northern Park Boundary are not yet complete. The scale 1:125,000 was considered because of the availability of topographic maps of the Park, but again, no topographic maps at this scale exist outside of the Park. A base map at a scale of 1:500,000 was considered because the state geologic map is at this scale, however no topographic map is available at this scale, and the working group felt that the precision implied by this scale might be too generalized. For this reason, smaller scale maps were rejected. The 1:250,000 scale topographic map base was selected because of its availability, the precision the scale implies, and the manageability of the map for presentation at meetings and in regulation.

B. BOUNDARY TYPES

Several boundaries are shown on the Controlled Groundwater Area Map overlay. The outer-most boundary is the line which separates those areas within the recommended Controlled Groundwater Area and those outside the Controlled Groundwater Area. The rest of the boundaries are nested within the Controlled Groundwater Area and separate different parts of the hydrothermal-flow system (recharge area (R-1 and R-2); discharge area (D-1 and D-2)) and different control objectives. This section describes the location of the areas and the basis upon which the boundaries were drawn. In this section several place names are used which do not appear on the Controlled Groundwater Area Boundary Map. The map was drawn on an acetate overlay on 1:250,000 scale Army Map Service (AMS) 1 x 2 degree quadrangles. The assumption is made that the reader is looking at Controlled Groundwater Area Boundary Map in overlay form on this AMS base. The section further uses geologic features in some areas to control the boundaries. These features are not shown on the Controlled Groundwater Area Boundary Map, but the references indicate the source map for these features.

1. Controlled Groundwater Area Boundary. The Controlled Groundwater Area Boundary for the hydrothermal-flow systems was drawn in working-group sessions with assistance from other professionals who were able to attend the session and from external technical reviewers who were available to read the document on short notice and wished to comment (see acknowledgements). The outermost boundary was delineated based on the distribution of the topographic divides, Madison Group outcrop and potential subcrop, possible fracture systems, and their implications for recharge, transmission, and discharge in the hydrothermal-flow system. The entire Controlled Groundwater Area Boundary can be broken into four major component areas in Montana. The factors that controlled the boundary

position are summarized moving clockwise along the Park Boundary from the southwest to northeast. The boundaries are broken into areas to simplify and organize the written discussion. For this reason, areas one through four are not marked on the Controlled Groundwater Area Overlay Map.

a. The boundary for the **first area** extends from the Montana-Idaho border to the Hebgen Fault (U.S. Geological Survey and others, 1964) on the northern margin of Hebgen Lake. The outermost boundary for this area was drawn from the northwestern end of the Bald Peak Syncline (Witkind, 1972a) where the Madison Group outcrops near the Montana border, along the Paleozoic/Precambrian Contact, across the Precambrian rocks to the edge of the alluvial fill material of the obsidian sand plain (Ross and others, 1955; Pierce, 1979; Witkind, 1972a) thought to contain discharging thermal water, and then north to the Hebgen Fault along the northern margin of Hebgen Lake (see Controlled Groundwater Area Overlay Map and Base Map).

This area is thought to encompass the hydrothermal-flow system for several reasons:

1. There is some warm-water discharge at the surface in the Hebgen Lake area (1:250,000 Ashton Quadrangle). Although these springs stopped flowing after the Hebgen Lake Earthquake, thermal discharge from the Park is possible in this area.

2. There is weak evidence of elevated temperature in a well at Bakers hole (16 degrees Celcius (C)) as well as in a flowing artesian well at the Povak Ranch (John Sonderegger and Wayne Hamilton, 1992, personal communication).

3. Hydrothermal outflow is also indicated by the chloride flux leaving this part of the Park (Fournier and others, 1976; Friedman and Norton, 1990).

4. The area contains the Bald Peak syncline which involves Madison-Group rocks, plunges toward the Park (Witkind, 1972a), and may recharge thermal systems in the Park. Hot springs to the southeast on the Park Boundary occur on trend with the axis of the syncline and may be connected.

5. The area is in a region of tectonic extension (Sbar and others, 1972; Witkind, 1972a; Bailey, 1977; Qamar and Stickney, 1983).

6. The area is close to the caldera rim (Smith and Christiansen, 1980; Christiansen and Hutchinson, 1987; Taylor and others, 1989).

7. The area is active seismically (U.S. Geological Survey and others, 1964; Qamar and Stickney, 1983)

b. The boundary for the **second area** extends from the Hebgen Fault (U.S. Geological Survey and others, 1964) along the north edge of Hebgen Lake (see Controlled Groundwater Area Map overlay). The boundary turns north and generally follows the western edge of the Madison Group rocks in the Madison Range. This margin is the west limb of a south-east plunging synclinorium (Ross and others, 1955). Mississippian Madison Group rocks are part of the structure and may potentially recharge the system. Some deep recharge in fractures may also occur in this area. Based on what appears to be a fault cutoff near Cameron, Montana (Tysdal and others, 1986) the boundary was carried eastward at Cameron across the synclinorium along a line just north of the Madison Group outcrops. The line was projected eastward from the last Madison Group outcrop to the Gallatin River. The line then follows the Gallatin River down stream to the point where the River crosses the Mississippian Madison Group outcrops. This crossing point is a good boundary location since the Gallatin River would probably constitute a constant-head boundary if the River recharges the limestone in this area. The boundary then extends to the Gallatin River-Yellowstone River divide on an azimuth that connects this part of the boundary to the known southwestern extent of the Paradise Valley-Deep Creek fault system (Personius, 1982).

This second area is thought to encompass the hydrothermal-flow system for several reasons:

1. The area encompasses surface-water flow (recharge) to the Park based on topographic evidence and watershed analysis along the western boundary of the Park to the north of the Hebgen Fault (U.S. Geological Survery and others, 1964).

2. The boundary encompasses potential recharge from Madison Aquifer down the plunge of a synclinorium. (The plunge of the synclinorium is uncertain, but is potentially toward the Park (Ross and others, 1955).)

3. Comparison of Madison Group outcrops with elevation data on the base map show Madison Group elevations of more than 10,000 feet. These elevations are consistent with heads at mapped thermal springs in the Park.

4. There are travertine-bearing thermal springs in the northwest part of the Park along the caldera rim (Terrace Springs) which conceivably could be related to Madison-Group recharge outside the Park.

5. The deuterium data suggest high-altitude recharge is possible from this region (Rye and Truesdell, 1992).

c. The boundary for the **third area** extends from the known end of the Deep Creek extensional-fault system to connect with the northern part of the Bear Creek watershed divide (see Controlled Groundwater Area Map overlay).

This third area is thought to encompass the hydrothermal-flow system for several reasons:

1. There is geochemical (chloride) and isotopic (helium) evidence that the hydrothermal system MAY be connected along fault systems extending out of the Park called by some the Reese Creek-Gardiner fault system at LaDuke Hotspring (Sorey, 1991).

2. The structures are connected to hydrothermal outflow in this area (Struhsacker, 1976; Sorey, 1991)

3. The deuterium data suggest recharge from this area is possible (Rye and Truesdell, 1992).

4. Sulfur isotope data suggest anhydrite sources likely associated with Madison Group (Sorey, 1991).

5. There is some magnetotelluric evidence of a heat source near Bunsen Peak (Sorey, 1991).

6. The area is near visible extensional-fault scarps on the eastern margin of the Paradise Valley fault system (Qamar and Stickney, 1983; Personius, 1982).

b. The boundary for the **fourth area** extends from the eastern Bear Creek drainage divide along the drainage divide that sheds surface water into the Park. This divide extends to the Wyoming border and is the Park Boundary, where the Park Boundary is the divide near Cooke City, Montana (see Controlled Groundwater Area Map overlay).

This area is thought to encompass the hydrothermal-flow system because:

1. The isotopic evidence suggests recharge is possible here (Rye and Truesdell, 1992).

2. Watershed analysis of surface-water flow suggests groundwater recharge.

3. The area encompasses the Madison Group near Cooke City, Montana and rocks in the area are likely fractured (Elliot, 1979; Lovering, 1929; Pierce and others, 1973; Pierce, 1987).

This area caused considerable discussion during review because the boundary is coincident with the Yellowstone National Park Boundary in the northeastern corner of the Park. Some have suggested that Madison Group rocks were incorrectly eliminated from the boundary. These outcrops are too small to plot at a scale of 1:250,000, are very close to the controlled groundwater area boundary (within the line resolution of the boundary line width (0.25 mi.), and in the opinion of the working group are isolated from flow systems discharging toward the Park by extensional faulting in the break-away fault zone (Elliot, 1979; Pierce and others, 1973, and Pierce, 1987). The working group is aware of no evidence of recharge to the Park in the bedrock east of the drainage divide in this area.

2. Subareas within the Boundary. Inside the Controlled Groundwater Area Boundary are four subareas (two recharge and two discharge). There is a region of potential recharge to the hydrothermal system that is outside the topographic divides which control surface-water flow into the Park. In these areas there is potential recharge through the Madison Aquifer or deep fractures (R-1). This recharge flows toward the heat source and eventually to hydrothermal-discharge areas. There is a second area of recharge within the topographic drainage divides which sheds shallow groundwater through alluvial fill into the Park (R-2). No interaction is now known between the shallow alluvial (R-2) recharge and the hydrothermal-flow system, but deuterium data permit the possibility of high-elevation recharge to the hydrothermal system (Rye and Truesdell, 1992).

In general, all regions of probable hydrothermal discharge are collected together (D-1). Additional monitoring and control are desirable for hydrothermal water which discharges directly adjacent to the Park (D-2) because of possible interactions between head decline outside the Park and heads in the hydrothermal system in the Park. A hypothetical example illustrates the need for more stringent monitoring and control. If low levels of hydrothermal development were to occur 30 feet from the Park Boundary some impact on the hydrothermal system is likely (but not certain). Such impacts might occur quickly. To insure adequate review in such settings the D-2 area is proposed. A problem remains however. How far from the Park boundary in discharge areas should this more stringent control extend? The distance is difficult to establish without site-specific data. Some insight is provided from New Zealand. Hydrothermal-water withdrawals at Rotorua in New Zealand by approximately 500 domestic and hotel users was sufficient to impact thermal features nearby. The New Zealand government eventually cemented shut hydrothermal- production wells within 1 mile of Pohutu Geyser. Within months, the pressure levels recovered and the Pohutu geyser returned to normal behavior (Allis and Lumb, 1992; Cody and Lumb, 1992). Although there are no geysers directly adjacent to Yellowstone National Park, this distance multiplied by a safety factor of two seems prudent for increased vigilance. While one might justify distances of up to 8 miles for the D-2 area based on impacts in other regions, such impact distances have historically been associated with large-scale withdrawals for power generation

and can be addressed under D-1 controls. The designation of two discharge areas recognizes that even small scale development close to Park hydrothermal discharge areas may impact the hydrothermal flow system in the Park quickly. Little time between development and monitored change may exist. Further from the Park, small-scale development is less likely to impact the Park and even if such development were ultimately to be shown likely to impact the Park, more time is available to collect data, monitor, and analyse the impact. The D-2 areas thus should have more stringent monitoring and control measures than the D-1 areas. In some cases deep recharge occurs via the Madison Group or fractures which may exist below the shallow recharge areas or thermal discharge areas. In such areas two letter designations appear with the first the dominant and the second the secondary concern (eg. D-1 + R-1).

3. Boundary-Line Precision. Review of the criteria used to locate the Controlled Groundwater Area Boundary reveals that the precision of the line is low. While one might be tempted to draw a razor sharp line around the area (and indeed one could), the actual line should be viewed as a broad line best drawn with a wide pen. On the other hand, although the line is generalized, the position of the line was drawn to encompass certain hydrologic and geologic features and so should be viewed as carefully located given the data available.

IV. Baseline Data Collection and Monitoring

There are three tasks related to assessment of impact on the hydrothermal system in Yellowstone National Park. The first task is characterization of baseline conditions. The second task is establishment of long-term trends in water levels and chemistry outside of developed areas at selected sites, so that impacts from development can be placed in a regionally unimpacted framework. The third task is monitoring of specific groundwater development activities where such monitoring is warranted.

The characterization of groundwater from wells and springs has been broken into four categories, based upon the heat content of the water. The temperatures selected are based on White and Williams (1975). Normal temperatures are less than 59 degrees Fahrenheit (F; 15 degrees Celsius, C); thermally anomalous waters range from 59 to 90 degrees F (15 to 32 degrees C); warm waters range from 90 degrees F up to but not including boiling (the temperature of boiling will vary as a function of altitude, but is approximately 200 degrees F (93 degrees C) within the Park; and hot if the temperature exceeds 200 degrees F. Thermometry is discussed by Rybach and Muffler (1981). The intensity of baseline data collection and analysis should be tied to the temperature category and intensity of use (see tables which follow).

A. Baseline Data

Baseline data collection should consist of:

1. An inventory of springs and thermal features within the Park, within at least two miles of the boundary.

2. An inventory of wells, springs and thermal features outside the Park, but within the Controlled Groundwater Area, is desirable. All wells should be inventoried. As a minimum springs within two miles of the boundary should be inventoried.

3. Geophysical characterization (see implementation).

The importance of solid base-line data through time cannot be over-emphasized. At Rotorua, researchers "....described many changes, not all of which are necessarily or obviously consistent with declining geothermal field. There is a background of both decline and recovery of individual features against which it is difficult to detect a consistent trend, and it is only through a broad-based approach, which looks at the field as a whole, that this has been possible" (Cody and Lumb, 1992, p. 218). Natural changes and variability can easily obscure changes due to human impacts. For example, monitoring-well levels at Rotorua in New Zealand were effected by natural changes, withdrawal changes, barometric changes, rainfall pattern changes, long-term rainfall changes, temperature changes, and boiling changes (Bradford, 1992, p. 234-5) The same can be expected for other parameters. If one is to know of impacts to the system, the natural temporal and spatial variability of the system must be recognized and accounted for in the inventory and baseline-data-collection programs. The National Park Service should increase its mandated inventory and monitoring of thermal features.

Because drilling is not considered a viable option within the Park, all sampling will have to be from natural discharge areas. The inventory of springs and thermal features within the Park should include water temperature, discharge rate, and chemistry.

The inventory of wells, springs and thermal features outside of the Park should include elevation of the well or spring (low-resolution global positioning is urged as a minimum since topographic-map-elevation data are inadequate for analytical purposes), depth to water or shut-in pressure for wells or flowing wells, temperature, specific conductance, discharge for springs and pumping rate for wells, and chloride content.

A representative sampling of existing wells requires both areal distribution and wells completed in different hydrogeologic units. For the purposes of this baseline, the two major units are bedrock and unconsolidated fill materials. In addition to standard requirements for well-drillers reports, permitting for new wells should require the driller or owner to provide well information including location to quarter-quarter-quarter-quarter section, ground elevation at the well, and temperature. Inspection of reports for compliance is recommended. For wells with temperatures greater than 59 degrees F, or discharges greater than two acre feet per year, or areas where cumulative effects are a concern, additional requirements may be imposed, such as measurement of specific conductance (SC), and chloride. Equipment for SC and chloride determination might be maintained for driller/owner use by the National Park Service at Mammoth and West Yellowstone. Measurement and reporting requirements are graduated based on temperature and metered water use. A useful reference on the chemistry of geothermal systems is Ellis and Mahon (1977).

If possible, five wells or springs should be selected in each of the subarea categories (R-1, R-2, D-1, D-2; 20 sites) and should be sampled for "complete" chemistry, gas analyses, and isotopic analyses described in the table footnotes. The purpose is to supply background data as a reference against which later measurements from developed areas can be compared, analyzed and interpreted.

Geophysical baseline data should be collected within and along the borders of the Park to provide a reference data set. Within the Park, non-invasive geophysical techniques for gathering baseline data and for monitoring possible impacts are appropriate and potentially very useful. Monitoring of earthquakes within or near the Park provides useful data and should be continued, preferably with an enlarged network. For monitoring purposes, shallow, microearthquake activity should receive increased emphasis.

Another potentially useful data set would be provided by microgravity and precision elevation measurements. For purposes of monitoring any potential effects from development, any effects due to tectonic sources would have to be determined and subtracted (i.e., this is needed baseline data prior to any significant development). Other passive geophysical techniques, such as magnetotellurics and self potential surveys, that could be useful for monitoring the potential effects of geothermal development should be investigated. For any of the non-invasive geophysical techniques, participation at the federal level will be required because of equipment and cost constraints.

B. Long-Term Reference Data Collection.

A program is needed to collect reference data through time. Some wells and springs inside and outside the Park should be selected after the baseline characterization program is completed. The decision as to which wells and springs and what data is required should be left to the Technical Advisory Board since

decisions should be based on the results of the characterization. Quarterly monitoring early in the program could be followed by annual monitoring later under the guidance of the Technical Advisory Board.

C. Monitoring

The following monitoring approach is recommended:

1. All wells must be metered, and provide annual reporting of appropriate items in the following tables:

Table 2. Reporting and monitoring requirements within R-1 R-2 and D-1 Subareas. (Q=Discharge; WL=Water Level; T=Temperature; SC=Specific Electrical Conductance)

Temperature	Q< 2 acre-ft/year[1]	Q> 2 acre-ft/year
<59 degrees F	Q and T	Q, T, and WL[2]
60-89 degrees F	Q, WL, Chloride, SC and T	Q, WL, Chemistry[3], & T, for production well
90-200 degrees F	Q, T, Chemistry[4], 2 monitoring wells[7]	Q, T, Chemistry[6], Geophysical update[5], 4 monitoring wells[7]
>200 degrees F	Q, T, Chemistry[6], Geophysical update, 4 monitoring wells[7]	Additional regulations besides those for < 2 acre-ft/year[7]

Table 3. Reporting and monitoring requirements for D2 Subareas.

Temperature	Q< 2 acre-ft/year[1]	Q> 2 acre-ft/year
<59 degrees F	Q, T, WL	Q, T, SC and WL[2]
60-89 degrees F	Q, WL, Chloride, SC and T	Q, WL, Chemistry[3], SC & T, for production and 2 monitoring wells[7]
90-200 degrees F	Q, T, Chemistry[4], Geophysical update[5], 2 monitoring wells[7]	Q, T, Chemistry[6], Geophysical update, 4 monitoring wells[7]
>200 degrees F	Q, T, Chemistry[6], Geophysical update, 4 monitoring wells[7]	Additional regulations besides those for < 2 acre-ft/year[7]

[1]This category (with use less than 2 acre-ft per year) requires that the well not exceed 6 inches in diameter, that the pump not exceed 2 horsepower, and that the well not exceed 300 feet in depth.

[2]Both static and pumping water levels required.

[3] Complete chemistry including all inorganic major, minor, and trace constituents normally analyzed by EPA certified laboratories. This analysis will help both with system analysis and assessment of potential health concerns associated with use of thermal water as a drinking-water supply. Values for pH, temperature, specific conductance, and alkalinity should be determined in the field.

[4]Chemistry to include additional components (gases or isotopes) at the discretion of the regulatory agency. Careful attention must be paid to correct sampling procedures for the gas analysis. Sampling procedures should be guided by the Technical Advisory Board.

[5]An annual microgravity and precision elevation survey may be required before production begins upon the recommendation of the Technical Advisory Board/Regulatory Agency when deemed appropriate.

[6]Chemistry should include all relevant isotopes and gases in addition to a complete inorganic analysis. Gas chemistry should include, but not be limited to, the following: N_2, NH_3, CO_2, CH_4, H_2, H_2S, and the noble gas series ^3He, ^4He, ^{36}Ar, and ^{40}Ar, in order to characterize the water(s) being produced for comparison with Park waters (Sorey, 1991). Sampling procedures should be guided by the Technical Advisory Board.

[7]Data to be reviewed/analyzed by the Technical Advisory Board and/or regulatory agency identified in Section V.

Temperatures rather than heat flow values were chosen as thresholds in Tables 2 and 3 because temperatures are more easily explained to the public who ultimately will be impacted by the groundwater monitoring and control. Furthermore, there are technical problems with the measurement of heat flow as well as temperature in wells which produce water. Problems include mixing of hot and cold water, time of equilibration, measurement under static or flowing conditions, and impacts of well completion procedures. Given these potential problems water temperature is a more straightforward parameter upon which to base reporting and monitoring requirements. All temperatures in Tables 2 and 3 are in degrees F since this is the temperature system most lay people are familiar with. Some explanation of the origin of the temperature thresholds may be helpful:

59° F 15° C -- This is the temperature threshold between thermal and non- thermal water. (White and Williams, 1975, Table 1 caption). Geothermal resource inventories in the region also used this value (Sonderegger and Bergantino, 1981; Heasler and others, 1983) The 59° C (15° C) threshold was dictated by the Department of Energy Program which funded both Sonderegger and Bergantino, 1981 and Heasler, 1983 (Sonderegger, personal communication, 1992).

90° F 32° C -- This is the temperature above which commercial development would be considered feasible, but below which such development would likely not be feasible. (Note: this temperature threshold is based on the experience of members in the working group).

200° F 93° C -- This is the approximate boiling temperature of water in the vicinity of Yellowstone. Local drillers with little hot- water drilling experience commonly are not competent to handle temperatures at and above this range. As a result there is risk of loosing a well during drilling if experienced and technologically sophisticated drillers are not used. (The temperature value was rounded. The temperature varies with elevation, and a representative and easily measured and remembered value was selected.) This temperature is supported approximately in U.S.G.S. Circular 726, (Table 1, item 1 b (3) which distinguishes low and intermediate temperature systems based on a 194° F (90 C) threshold.

The discharge thresholds were selected to distinguish low level domestic personal use of water from those which are more likely commercial in nature. In general homes do not use more than 1 acre-foot of water and certainly not more than 2 acre-feet. Two acre feet of water is approximately 650,000 gallons. This represents the use of about 1800 gallons of water per day. The use of meters on wells is recommended to assess the actual water used. Most individuals have little idea how much water is actually used. Pumping rates are poor direct indicators of water usage because wells are typically not pumped continuously. A 10 gpm well can produce 14,000 gallons per day or about 5 million gallons per year. Many domestic wells are capable of producing at this rate, but few if any homes use this much water because

well usage is intermittent not continuous. Metering will provide hydrogeologists with realistic data regarding actual usage so that reasonable monitoring and review of impacts on the hydrothermal system can be achieved.

Outside of the Park but within the Controlled Groundwater Area, the Regulatory Agency will periodically analyze hydraulic head data and assess cumulative impacts. In areas of recharge transmission to the hydrothermal system, the depth and geologic unit from which a well draws water largely determines its threat to the hydrothermal-flow system in the Park. Deep wells, that are cased to exclude water from alluvium and near-surface bedrock, may draw water from rocks or zones that directly connect recharge to the hydrothermal-flow system. Such withdrawals of groundwater might deplete recharge to the hydrothermal flow system and ultimately impact the system in the Park. Depending on the amount of withdrawal, distance from the Park, and nature of the flow connections, the impacts might be delayed for many years but could still produce human impacts on the flow system for future generations. Wells cased to specifically withdraw water from the Madison group rocks or a highly transmissive fracture system require individualized attention to data obtained from post-drilling tests to insure recharge to the hydrothermal system is protected.

Any wells that produce waters that qualify as warm or hot will need more intensive monitoring and/or analysis to assure that they will not impact the Park's hydrothermal system. Geophysical baseline information would be required when warm or hot waters are encountered within the Controlled Groundwater Area, and large-scale withdrawals are contemplated. Data collection should consist of characterization adequate to indicate the depth and lateral extent of the reservoir zone. Microgravity and precision elevation surveys should be implemented prior to production and be followed by microgravity and precision elevation surveys through time as deemed necessary by the Technical Advisory Board. Additional geophysical information may be required by the Technical Advisory Board.

Thermal water development within this zone will require intensive monitoring of both pressures or water levels and water chemistry (liquid and contained gases). Initial characterization of water levels or pressures and of the thermal-water chemistry at the production site(s) and the monitoring network must be very complete. These data will become the baseline used to indicate whether a change in the water chemistry or hydraulic gradient is occurring. Any significant change such as a 50 percent increase in chloride levels that suggests that thermal water from the Park is becoming a larger component fraction in the production water will be considered grounds for presuming that the Park is at risk. Significant reduction or cessation of water production is required. The regulatory agency with the advice of the Technical Advisory Board is responsible for determination of which alternative is required. Other tests of significant change may be implemented by the Regulatory Agency in consultation with the Technical Advisory Board.

When monitoring wells at a site are required, the monitoring network must consist of two to four wells in addition to the development well. The monitoring wells will normally trend toward the Park, or be keyed toward the source zone as indicated by the geophysical study. These wells must be completed in the production horizon and be shown to respond to the production-well pumpage or production. When four wells are required, the outer well may not be able to show response to the development production initially, it must be completed so that the water chemistry strongly indicates that these wells are part of the same flow system. When monitoring wells are required, the regulatory agency should review and approve the locations of monitoring wells prior to installation, and should review the adequacy of the performance after installation.

Extreme care should be used in any baseline or monitoring program where wells are used. Proper design of the wells is imperative. Indeed one could argue that installation of even a monitoring well directly adjacent to the Park could constitute a threat to the hydrothermal system since wells can decrepitate or can be designed incorrectly. If pressures are high, leakage or new flow at the surface can have the same effect as development even if development does not occur.

2. Discharge Area (D-2). The recommendations above would not preclude an appropriator from drilling a well directly adjacent to the Park to extract thermal water. Clearly, a withdrawal at the Park Boundary would very likely (though not certainly) impact the hydrothermal-flow system in the Park. This leaves a question. "How far from the Park Boundary should every well which withdraws water warmer than 15 degrees C be scrutinized individually for impact on the Park." This distance is of course difficult to estimate without site-specific data. However, withdrawal of hydrothermal water at Rotorua in New Zealand by domestic and hotel users was sufficient to impact geysers near by. The New Zealand government eventually closed about one-third of the active wells which used thermal water and reduced withrawals by about 70 percent within 1 mile of Pohutu Geyser. Within months, the pressure levels recovered and the Pohutu geyser returned to normal behavior (Cody and Lumb, 1992). Although there are no geysers directly adjacent to the Yellowstone National Park, this distance times a factor of safety of two seems prudent for well-by-well analysis of well effect and cumulative effects regardless of pumping rate. This discharge area boundary (D2) at two miles is recommended for increased vigilence.

V. Implementation

A Technical Advisory Board, with members familiar with Montana's geothermal resources and/or geothermal exploitation, should be instituted to meet as needed to assist the Department of Natural Resources and Conservation in administering this Controlled Groundwater Area. One function of the Board should be technical assistance in the updating or modification of the criteria and/or boundary of the Controlled Groundwater Area. A second function of the Board would be to

provide technical assistance on the assessment of cumulative effects of development within the Controlled Groundwater Area. A third function is to periodically review hydrologic data relevant to protection of the Park to determine whether the system may be impacted. A fourth function is recommendations regarding a long-term reference-data collection. A fifth function is review of monitoring plans where required.

The use of a Technical Advisory Board follows the model established for the Long Valley, California, KGRA, (Farrar and Lyster, 1990; Lyster, 1991) and should utilize representatives from the geothermal industry, state agencies (DNRC, RWRCC, DHES, EQC, MBMG), federal agencies (USGS, NPS, USFS, SCS, EPA), the consulting profession, and possibly the university community. The key is to have representatives that understand hydrothermal systems and the application of geophysical and geochemical data in understanding flow systems. In order to safely permit development of thermal waters while still protecting the Park, an understanding of the controls on the system being developed is mandatory. The function of this committee should be solely technical. Technical review would occur annually, or when the DNRC Water Rights Bureau was concerned about a particular well or application and determined that more detailed review was appropriate. Political review of projects and impacts would fall to a political group (RWRCC or the like).

Water-related data collection, storage, and dissemination should be assigned to the Groundwater Information Center in the Montana Bureau of Mines and Geology. This assignment should not be made without funding the collection, storage, and dissemination activities.

If no funds are allocated for characterization, baseline, or long-term reference data collection, one would have to question the commitment to protect the hydrothermal system in the Park.

VI. Additional comprehensive data collection needs.

Several additional data collection efforts are strongly recommended to assist with interpretation of inventory, baseline and monitoring data.

1. Complete a map of surface hydrothermal features in Yellowstone National Park.

2. Review of the geologic mapping adjacent to the Park indicates that significant work remains to understand the structural and stratigraphic architecture of the system. As a minimum, well constrained compilations of geology on the Bozeman, Billings, Cody, and Ashton 1 x 2 degree AMS quadrangles is needed. In addition, much field work on the geology remains to be done both on the surface and in the subsurface (geophysically) below the Gallatin Volcanic Field. Once compilation is

complete, detailed mapping in problem areas at 1:100,000 or even 1:24,000 may be necessary in some areas.

3. Experiences elsewhere suggest that changes due to development can be detected, but only if predevelopment data are available. In the case of subsidence, a very sound network of precision elevation data is needed. Such a network might be established in conjunction with a well-head elevation measurement program for efficiency, but reoccupation of older topographic survey points should not be ignored. Analysis must recognize the potential for a tectonic component in the elevation-change data as well as the possibility of human-induced components. Monitoring of microearthquakes should also be encouraged. Exploration of thermal infrared, microgravity, magnetotelluric surveys is recommended. None of these data should be considered a substitute for sound long-term reference data collection.

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APPENDIX J

DEFINITIONS - **Hydrologic Terms**

Acre-foot: A unit of measure commonly used to express water volume. One acre foot of water will cover one acre of land to a depth of one foot. This equals 325,851 gallons.

Actual Consumption: Also termed "net depletion." The actual amount of water consumed by a water use. Water diverted is generally not totally consumed and some of the water returns to the stream.

Appropriation: Use of water recognized under state law.

Average/Mean Monthly Flow: The average rate that a stream flows during a given month, expressed in cubic feet per second (cfs). Averages are calculated from stream flow measurements (stream gage records). Rates generally differ for each month of the year due to the seasonal nature of temperature and precipitation.

cfs: A unit of measure used to express stream flow rates. The letters stand for cubic feet per second.

Consumptive Use: Refer to non-consumptive use.

Estimated Average Monthly Flow: An estimate of the true average monthly flow of a stream. Estimates are obtained through indirect methods when stream gage records are not available.

Groundwater: Water existing beneath the ground surface.

Instream Flow: Water remaining in the stream channel which is not available for consumptive use. Instream flow is needed to sustain stream channel values, fish and wildlife populations, streamside habitat and water quality and provide for recreation activities.

Mean Monthly Flow: See Average Monthly Flow

Minimum Flow Requirement: The minimum flow rate which is designated to remain in a stream channel for instream flow purposes.

Non-Consumptive Use: When applied to mining or hydropower use with a priority date of January 1, 1993 or later, refers to appropriations not causing a net loss in the source and where water is returned to the stream with little or no delay and without adverse effect of the quantity or quality of water. Relating to other uses, refers to a water right considered to be non-consumptive by the decree, permit or law authorizing the use.

Quantification: The process of measuring, quantifying, or allocating water to a particular use.

Riparian: Relating to the general streamside (sometimes lakeside) environment.

Watershed: The area drained by a stream system. A watershed is defined by the topographic divide, and several watersheds fit together to form a river basin.

Revised 3/94

APPENDIX K

DAVID T. AMMAN
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EDUCATION: B.S. Watershed Science, 1985, Utah State University, Logan.

EXPERIENCE:

Hydrologist / Program Manager:
Montana Water Measurement Program
Helena, Montana
January 1997 - current

* **Field Measurements: streamflow, channel geometry**
* **Installation and rating of measurement structures**
* **Water Rights Compilation and Analysis**

Hydrologist:
Montana Reserved Water Rights Commission
Helena, Montana
November 1991 - December 1996

* **Field Measurements: streamflow, channel geometry**
* **Water Rights Compilation and Analysis**
* **Flow Estimation, Frequency Analysis, Statistics**

Hydrologist:
Schafer and Associates
Bozeman, Montana
October 1990 - November 1991

* **Surface Water Measurements**
* **Technical Report Writing and Graphics**
* **CADD and Data Reduction**

Basin Planning Technician:
King County Basin Planning
Seattle, Washington
October 1988 - October 1990

* **Riparian and Land Use Mapping and Quantification**
* **Report Preparation, CADD, Art and Graphics**
* **Field Measurements: channel geometry, streamflow**

Hydrologist:
USDA Forest Service
Moscow, Idaho
June 1988 - October 1988

* **Installed / Operated Rain Simulation Equipment**
* **Collected Soil Bulk Density Samples**
* **Installed / Operated Portable Flumes**

Geologic Technician:
North American Exploration
Kaysville, Utah
August 1985 - November 1987

* **Collected and Processed Stream Sediment Samples**
* **Reduced and Organized Data for Technical Reports**
* **Analyzed Soil and Topographic Maps**

Hydrologic Technician:
USDA Forest Service
Encampment, Wyoming
June 1983 - June 1985

* **Installed and Maintained Remote Climatic Stations**
* **Reduced Data: Streamflow, Snowpack, Precipitation**
* **Conducted Snow Surveys and Channel Assessments**

REFERENCES:

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EDUCATION

Snow College, Ephraim, Utah, 1948
Major: Agriculture and Agronomy
Minor: Chemistry

Utah State University, Logan, Utah, 1950
B.S. Major: Agronomy and Soils
Minor: Botany

Iowa State University graduate school, Ames, Iowa, 1972
Major: Soil Chemistry and Engineering
Minor: Plant Physiology

EXPERIENCE

Soil Scientist (Research Specialist)
Montana Reserved Water Rights Compact Commission, DNRC, Helena, Montana 1989-Present
Soil scientist for the Montana Reserved Water Rights Compact Commission and other agencies as assigned. Provides information on soil characteristics, land classifications and related data. Performs field investigations and advises the Compact Commission as to the suitability of soils for agricultural irrigation and other uses. Completes reports for each study area and participates in reserved water rights negotiations.

Soil Specialist
U.S.D.A. Soil Conservation Service, Bozeman, Montana 1976-86
Soil specialist for Soil Conservation Service. Provided technical soil expertise to seven soil survey areas in central and western Montana. This involved the classification, checking, field mapping, laboratory interpretations of soils, and preparing manuscripts. Major publications: *General Soils Map and Interpretations of Montana Soils, Missoula County Soil Survey, Blaine County Soil Survey, and Madison County Soil Survey.*

Soil Scientist-Soil Survey Supervisor
U.S.D.A. Soil Conservation Service, Missoula MT 1971-76
Survey supervisor for Missoula County. This position involved soil mapping, classification and laboratory interpretations of soils in Missoula County and other areas as assigned. Also supervised the work of three to four soil scientists. Completed soil surveys and publications for Georgetown Lake area, Anaconda area and several special community projects.

Soil Scientist-Soil Survey Supervisor
U.S.D.A. Soil Conservation Service, Chinook Montana 1956-1971
Survey supervisor for Blaine County area. This position involved soil mapping, classification and laboratory interpretations of soils in Blaine County and other areas as assigned. Also supervised the work of up to eight soil scientists. Completed soil survey and reports on Beaver Creek Park, City of Havre, with interpretations for agriculture, sanitation, pollution, building sites, etc.

Soil Scientist and Irrigation Specialist
U.S.D.I. Bureau of Reclamation, Bismarck, North Dakota and Great Falls, MT 1950-1955
Soil scientist and irrigation specialist for the Bureau of Reclamation. This position involved soil mapping, classification of soils and work in field soils laboratory. Tests involved the chemical and physical properties of soils and soil moisture relationships.

SPECIAL SKILLS

Good speaking and writing ability. Working knowledge of soils laboratory equipment and procedures.

Craig C. Bacino

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EXPERIENCE

Geographic Information Systems (GIS) Specialist
Reserved Water Rights Compact Commission, Helena, Montana 1989-90, 91-96

Manage and operate staff GIS for State Commission negotiating reserved water rights with federal government and tribes. Develop and program applications, design databases, analyze data, prepare and present maps and reports, establish and supervise digitizing unit, manage team projects, convert legacy databases into GIS format. Systems administration, network staff computers, create and administer anonymous ftp and http (WWW) sites, develop experimental WWW access to State water rights database, initiate staff telecommuting.

GIS Specialist; Office Manager
GeoResearch, Inc., Billings/Helena, Montana 1990-91

Manage GIS portion of contracted environmental impact statement. Develop GPS/GIS applications, train users, and market company services.

Computer Systems Analyst-Programmer
U.S. Central Intelligence Agency, Washington, DC 1988-89

Initiate and manage Agency GIS lab. Develop and promote analytical and operational applications for inter-Departmental counternarcotics group. Systems administration, programming, cartography, training.

Geographic Specialist
U.S. Central Intelligence Agency, Washington, DC 1986-88

Procure maps and geographic information in West and Central Africa for Agency operations and collection. Gather requirements, identify data and sources, plan foreign procurement trips, collect data abroad, evaluate and disseminate information to users. Brief U.S. officials, maintain domestic and foreign contacts. nowledge of foreign affairs, politics, culture, geography, and French language.

Other Experience

Teaching Assistant, Dept of Geography, University of Montana, Missoula, Montana	1984-86
Claimstake Surveyor, Draftsman, Azimuth Inc., Missoula, Montana	1984-85
Freelance Cartographer, Missoula, Montana	1985-86
Art Director, Graphic Artist, Judge Advertising, Helena, Montana	1981-83
Art Teacher, Capital High School, Helena. Montana	1980-81
Forestry Technician/Crew Foreman, Boise National Forest, Idaho	1976-78, 85

COMPUTERS

Hardware

·Sun Sparc 2, 10, 20	·IBM PC	·Macintosh
·MicroVAX 3600 mini	·printers	·plotters, (pen, electrostatic/, inkjet)
·digitizing tables	·modems	·tape drives (9-track, 8mm, 1/4")
·CD-ROM players	·global positioning systems (GPS)	

Software

·ARC/INFO (workstation, mini, pc; GRID, TIN, ROUTE)

·GRASS	·AutoCAD	·GeoLink (GPS)
·ERDAS	·dBase	·word processing

Programming

·Basic	·FORTRAN	·C
·Bourne/C shell scripts	·CGI scripts	·HTML
·AML (ARC Macro Language)	·SML	·INFO
·AutoCAD menuing	·macro languages	·DCL (Digital Command Language)

Operating systems

·UNIX (inc. Solaris 1.x, to 2.x migration)		·Windows
·DOS	·Macintosh	·VMS

Networking

·anonymous ftp server	·http (WWW) server	·PC-NFS

EDUCATION

MA, Geography, University of Montana, Missoula, MT 1986

BFA, Fine Arts, University of Iowa, Iowa City, IA 1974

TRAINING

Central Washington University, Ellensburg, Washington

- *GRASS/GIS 4.0 Basic Course*
- *GRASS Advanced Course*

Environmental Systems Research Institute, Redlands, California

- *Introduction to ARC/INFO*
- *Introduction to Database Design*
- *Applications Programming*
- *Processing Techniques in INFO*
- *Geographic Analysis*

AutoDesk, Inc., Sausalito, California

- *AutoCAD Authorization Training*

Digital Electronics Corporation, Landover, Maryland

- *DCL Utilities and Commands*
- *VMS System Management*

PRESENTATIONS, ETC.

GIS Curriculum Advisory Committee, 1995, Division of Technology, Montana Tech of the Univ. of Montana, Butte, Montana

"GIS Disasters", 1995 Montana GIS Users Conference, Helena, Montana

"Integrating Spatial Data in a GIS", 1994 Water Resource Management Info Systems Conference, Albuquerque, New Mexico

"Formatting Data in Legal Land Descriptions", 1992 Montana GIS Users Conference, Butte, Montana

"GPS and Interfaces to GIS", 1990 Northwest ARC/INFO Users Group, Sun Valley, Idaho

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PROFESSIONAL LICENSES

Montana Bar #3589 (active)
Colorado Bar #021706 (inactive)
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EDUCATION

J.D. 1990

University of California, Hastings College of the Law, Magna cum laude
Assistant Editor, Hastings Constitutional Law Journal
Semifinalist, Environmental Moot Court Competition, Pace University, NY
Legal Writing Research Assistant

M.S. 1982, Geology

University of Washington
Teacher's Assistant: Introductory Geology, Economic Geology, Field Geology
Publications associated with thesis on chemical exchange between hot water and ocean crust:

1) Journal of Geophysical Research, vol.89 no.B5 pg. 3275 (1984)
2) EOS, Transactions of the AGU, vol.64, no.35, pg.533 (1983)
3) GSA Abstracts with Programs, vol.14, no.7, pg.62 (1982)
4) Marine Technology Society Journal, vol.16, no.3, pg.62 (1982) (published with co-author J.R. Delaney)

B.S. 1977, Geology

University of California, Davis
Departmental Award for Outstanding Achievement

WORK EXPERIENCE

Montana Reserved Water Rights Compact Commission
1520 E. Sixth Ave
Helena, MT 59620
1991 - Present

Legal Counsel to nine member Commission established to negotiate water right settlements with Indian Tribes and federal agencies. Chief legal counsel for negotiation of National Park Service - Montana Compact signed by the Secretary of the Interior on January 31, 1994. Chief legal counsel for the Compacts with the Chippewa Cree Tribe of the Rocky Boy's Reservation, the United States Fish and Wildlife Service, currently before the Montana Legislature

Colorado Supreme Court
State Judicial Building
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Denver, CO 80203
1991-1992

Judicial Clerkship with Justice George E. Lohr. Legal research for judicial opinions.

Natural Heritage Institute
San Francisco, CA
(415) 288-0550
Spring 1990

Part-time law clerk. Research on the legal/policy aspects of solutions to the agricultural drainage problem in the San Joaquin Valley, as part of the San Joaquin Valley Drainage Project.

California State Attorney General's Office
San Francisco, CA
Fall 1989, Summer 1988

Part-time law clerk, Environment Division. Research for cases enforcing California laws having to do with toxic and hazardous waste. Review of environmental impact statements.

McCutchen, Doyle, Brown & Enersen San Francisco, CA Summer 1989	Law Clerk. Research necessary to advise corporate clients on compliance with state and federal environmental laws including CERCLA and RCRA.
U.S. District Court, Northern California San Francisco, CA Spring 1989	Legal extern for Judge Robert Peckham. Legal research for judicial opinions.
Unocal Geothermal Santa Rosa, CA 1982-1987	Exploration geologist and development geochemist. Exploration and development of geothermal energy in California, Japan and the Philippines.

ADDITIONAL TRAINING

Harvard Negotiation Workshop and Advanced Negotiation Workshop, June 1994

LECTURES/PUBLICATIONS

Montana Water Law Conference, Sept. 1995, Helena
Speaker: "Practical aspects of negotiating federal reserved water rights"

Indian Water Rights Settlement Conference, Sept. 1994, Stanford
Speaker: "Implementing Settlements"

Indian Water Rights Settlement Conference, Sept. 1993, Bismark
Speaker: "Identifying Parties and Issues and How Negotiators Bind Larger Groups"

Rocky Mountain Groundwater Conference, Sept. 1994, Las Vegas
Speaker: "Changing Water Use and Water Law"

Co-editor: "Current Trends and Policies in Water Law," ABA, Section of Natural Resources, Energy and Environmental Law Publication

Co-author: "Negotiation of the Montana - National Park Service Compact," Rivers, vol. 5, no. 1, pg. 35, January, 1995

OTHER ACTIVITIES

Volunteer: Helena Big Brothers and Big Sisters
Denver Rape Crisis Hotline
Mile High Council, Girl Scouts of America

Interests include writing fiction:
Workshops: Yellow Bay Writers Workshop, University of Montana, 1990, with Joy Williams
Environmental Writing Institute, University of Montana, 1991, with Peter Matthiessen

Bill Greiman
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Objective

A career in water resource management.

Background

I was born in Sidney Montana in 1954 and grew up on a small farm-ranch 30 miles north of Glendive, Montana. I went to a one room country grade school and graduated from Richey High school in 1972.

Education

M.S. Agricultural Engineering, Montana State University, 3/90. Course work in surface and ground water hydrology, water resource management, economics, and alternate energy systems. Thesis work on the economics of irrigated agriculture.

Peace Corps Training, Bridgetown, Barbados, 11/80 - 12/80. Intensive six-week program which included courses in cross-cultural relations, economic and social development, and government operational structure.

B.S. Agricultural Engineering, Montana State University, 3/77. Awarded American Legion, FMC Corp., and University Engineering scholarships. Graduated with honors, GPA 3.32/4.0.

Experience

Civil Engineering Specialist IV, Reserved Water Rights Compact Commission (RWRCC), 3/90 - present. Leader of an interdisciplinary team that is responsible for the development of technical, political, and social information used in the preparation of a compact that will determine the reserved water right for various Indian Reservations and other Federal agencies in Montana. Also responsible for the development of the methodologies, irrigation system designs, and economic evaluations used in the determination of the "practically irrigable acres" of land on these Indian Reservations. This work also includes incorporating the computer aided design (CAD) work I prepare into the RWRCC's geographic information system (GIS) data base and coordinating all other GIS and CAD work.

Civil Engineering Specialist III, Montana Department of Natural Resources and Conservation, 9/87 - 3/90. Developed the engineering methodology, design standards, and graphics based computer model needed to prepare timely and correct irrigation feasibility evaluations for the water reservation program. Assess irrigability of preliminary irrigation proposals, and design and determine economic feasibility of those projects deemed practical. Evaluate and

review the work of engineering consultants. Assist in all aspects of preparing, evaluating, and presenting water reservation applications to the Board of Natural Resources. Responsible for coordinating the developing of the Water Management Bureau's geographic information system data base.

Resource Coordinator, Lower Yellowstone Conservation Districts Development Committee (LYCDDC), 3/84 - 6/87. Researched, evaluated, and reported on the methods and economics of new irrigation developments. Developed a two year scope of work including objectives, method of achieving objectives, time budget, and projected financial budget. Reported on irrigation design, methods of expanding existing systems, integrated farm management, irrigated crops, energy (existing, wind, solar, and biomass), federal power allocation, and economics of irrigation development. Developed computer "spreadsheets" for annual equipment costs, crop cost enterprise analysis, irrigation design and cost analysis, energy cost comparison, and crop water use estimation.

Soil and Water Conservationist, U.S. Peace Corps, Antigua, West Indies, 11/80 - 5/83. Advised the Ministry of Agriculture on soil and water conservation practices. Drafted a comprehensive proposal for the development of the island's water resources for irrigation and livestock use. Designed and supervised construction of six small dams for irrigation in rural village areas. Advised farmers on farming and irrigation practices. Repaired and maintained farm machinery and advised the Ministry of Agriculture on maintenance practices. Designed and constructed small agricultural equipment. Introduced and assisted farmers with alternate energy ideas. On completion of two years of service, was invited by the Ministry of Agriculture to extend my service.

Agricultural Engineer, Complete Irrigation Inc., Glendive, Montana, 4/77 - 10/80. Designed, sold, ordered, assembled, installed, and maintained irrigation systems. Duties included designing and assembling engine-pump units, welding pipeline fittings, developing price estimates, and supervising installation crews.

Hydrologic Technician, U.S. Bureau of Reclamation, Billings, Montana, 6/74 - 9/74 & 6/75 - 12/75. Collected irrigation canal data, interpreted two years of data, and supervised a crew of four for the Yellowstone River Basin Total Water Management Program.

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ACADEMIC BACKGROUND

- Master of Arts in History, University of Washington, Summer 1987
- Bachelor of Arts in History, University of Washington, June 1984

WORK EXPERIENCE

- June 1991 - Present: Historical Researcher/Technical Team Leader, Montana Reserved Water Rights Compact Commission, Department of Natural Resources and Conservation, State of Montana, Helena, Montana.

  Technical Team Leader for negotiations with Crow Tribe, Assiniboine and Gros Ventre of Fort Belknap Reservation, U.S. Fish and Wildlife Service, U.S. Forest Service, and National Park Service. Responsible for supervising technical research and analysis necessary for nine-member Commission to negotiate reserved water rights on assigned Indian or federal water reservations in Montana. Perform specialized historical research and prepare detailed memorandums on issues relating to federal reserved water rights such as priority dates, treaties, executive orders, legislative history, Indian Claims Commission cases, and more. Provide paralegal support to two staff attorneys. Responsible for writing, design, coordination and supervision of staff technical reports for finalized compacts, describing land and water resource information, technical work, and historical and legal factors for the Montana Water Court. Prepare memorandums presenting and explaining project ideas and results to the Commission and its negotiating teams. Prepare press releases, correspondence and coordinate information for public meetings and respond to public requests for information.

- June 1990 - May 1991: Office of the Dean, School of Medicine, University of Washington, Seattle.

  Responsibilities included acting as interim confidential Secretary to the Dean, and as secretary to Assistant to the Dean. Duties included transcribing confidential correspondence and reports, preparing Medical School Executive Committee minutes; assisting with maintenance of Dean's calendar and preparation of daily schedule of activities when required; screening calls regarding Dean's calendar; yearly coordination and production of Dean's Office Standing Committee list; assisting with record-keeping for Faculty Councils; supervising and allocating work to other secretarial staff; personnel work including initiation of hiring process, reference checks and coordinating interviews; handling confidential mail.

- 1987 - 1990: Researcher, Lane and Lane Associates, Seattle.

  Researched issues relating to Native American fisheries, land claims and water rights. Archive and library research. Organization and analysis of historical documents, published material, legal records, land records and state and federal records. Researched Bureau of Land Management (General Land Office correspondence records, Washington donation land claims, plat books, tract books), Bureau of Indian Affairs and Army Corp of Engineers record groups at the Seattle Branch of the National Archives. Have extensively researched 19th/20th century Washington territorial and state newspapers and unpublished manuscript material for Native American cultural information specifically relating to fisheries claims and claims for federal tribal recognition on coastal areas of Washington.

- 1988 - 1989: Research/writing.

  Work included drafting chapter on solid-waste and waste-water management to be included in a history of public works in Washington state, written by Paul Dorpat and Genevieve McCoy for the Washington state centennial celebration. Research and editing of historical script for the Laser Fantasy Grand Coulee Dam centennial light show, as well as consultation with script writers and designers. Collected Vancouver Island tribal and place names for a family history, and investigated pictorial and historical data for a novel set in 1897 Seattle. Co-authored article, "The Pollution and Protection of Puget Sound," with Lisa Mighetto, accepted for publication by the Institute of the North American West.

- 1986 - 1988: Assistant to University of Washington history professors Robert Burke, Jon Bridgeman and Daniel Waugh.

  Composed essay exam questions for approximately 100 upper level students per quarter, held review sessions for students, assisted students who had study problems, graded midterm and final exams, and guest lectured in Twentieth Century American History class.

- 1983 - 1985: Reporter during summer months for the Frontiersman and Valley Sun newspapers in Wasilla and Palmer, Alaska.

  Planned and wrote weekly historical series commemorating the New Deal colonization of the Matanuska Valley area. The project included use of 1935 photographs and text, interviews with original colonists, and culminated in a special edition coinciding with the annual Alaska State Fair. Also covered local government and school district issues, wrote articles and took photographs for local arts and entertainment, and assisted with editing and production of two newspapers.

- 1984 - 1985: While attending the University of Washington, stage managed two University theater productions.

  Coordinated the efforts of unpaid actors, set, light, costume and sound designers and

technicians. Set up auditions, kept rehearsals on schedule, arranged and attended all meetings between the director, cast and crew, ran the nightly production and managed production communications.

- 1982, Summer: Production assistant intern in Anchorage School District audio-visual center, Anchorage, Alaska.

  Taped and edited educational video tapes.

- 1981 - 1982: Office Manager for Arctic Sea, Inc., subsidiary of Community Enterprises Development Corp., Anchorage.

  Performed secretarial duties and bookkeeping for three-person office. Also assisted with proposal writing and with organizing and implementing projects designed to aid rural Alaska fishermen with development of marketing skills.

- 1979 - 1980, 1981: Assistant to executive director, Alaska Fisheries Development Foundation, Inc., Anchorage.

  Critiqued and summarized proposals and technical reports; performed secretarial duties.

AWARDS

- Alaska Press Association, 1985-1986. Second place, best breaking group of stories, non-daily newspaper, for articles concerning impeachment proceedings against former Alaska Gov. William Sheffield.

OTHER WORK AND ACCOMPLISHMENTS

- Publications: co-author, Rivers. "Negotiation of the Montana-National Park Service Compact," vol. 5, No. 1, January 1995, 35-45.

- Conferences/Training Seminars: Symposium on the Settlement of Indian Reserved Water Rights, Portland, Oregon, 1995; Eighth Annual Western Regional Indian Law Symposium, Seattle 1994; Twenty-sixth Annual Kyi-Yo Conference, Tribal Governments: Emerging Critical Issues, Missoula, 1994; Water Rights Workshop, Helena, 1992; Effective Presentations seminar, Helena, 1992; Team Building seminar, Helena, 1992; Coping with the Angry Public seminar, 1993; Montana History Conference, 1991; grant writing seminar, Seattle, 1987.

- Other Activities, and Positions held: National History Day judge, 1994 and 1995; former City of Helena/Lewis and Clark County Historic Preservation Commissioner ; former member Pacific Northwest Historian's Guild, volunteer in historic preservation for National Archives, Seattle Branch; theater stage manager and light board operator; bookkeeping assistant for Seward fisheries in Seattle; secretary and bookkeeper for Jalasko Associates in Alaska; page for Senate Finance Committee in Alaska Legislature; commercial fished set-net site at Coho, Alaska; assisted with family-owned trail-riding and guide service in interior Alaska.

RESERVED WATER RIGHTS COMPACT COMMISSION STAFF
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